FISHERIES DIVISION

MONTANA DEPARTMENT OF FISH,
WILDLIFE AND PARKS

Pollution Control Office

BIENNIAL REPORT 1982 - 1983

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Introduction

This report has been written to provide convenient access to data collected by the Pollution Control Office of the Montana Department of Fish, Wildlife and Parks. Much of the data is of a baseline nature and was collected as a yardstick against which to gauge future changes should they occur. Nevertheless, this information is reported, if for no other reason, to prevent needless duplication of the same work at some point in the future.

Some data on pesticide residues in fish that were collected by regional personnel are also included in this report because of the value of having the information in one document. Data collected by other individuals is appropriately acknowledged. Because of the wide variety of topics and objectives for collecting data, methods are discussed separately within each section of the report. This will prevent readers who are interested in a particular topic from having to search through other sections of the report.

Topics covered in this report include off flavor in fish flesh caused by domestic and industrial discharges into Big Spring Creek (Lewistown) and the Yellowstone River near Billings; transit time and flow speed measurements in various sections of the Madison River; gonadal development and food habits of brown trout in the Madison River above and below Ennis Lake; baseline water quality monitoring in Grasshopper Creek near Dillon, Lake Creek near Troy, and German Gulch Creek near Butte; metals and organic residues in the edible portions of fish from various locations in Montana; acid deposition monitoring of alpine lakes in southwestern Montana; and metals leachate experiments on smelter slag being used to sand roads in the Georgetown Lake area.

Flavor Tainting Tests

A variety of organic compounds are capable of imparting objectionable flavor to the edible tissues of fish. Examples include pulp mill effluent, oil refinery wastes, phenolic compounds, and numerous other chlorinated organic compounds including some pesticides (Shumway and Palensky 1973). To many Montana anglers, part of the pleasure associated with fishing is derived from eating the fish that are caught. This is recognized in Montana's Water Quality Standards, where it is written: "state waters must be free from substances that render undesirable tastes to fish flesh or make fish inedible." Clearly, adding substances to water that cause off-flavor in fish is an impairment of a beneficial use.

Montana streams that are suspected of receiving wastes that cause off flavor in fish include Big Spring Creek near Lewistown (Fig. 1) and the Yellowstone River near Billings (Fig. 2). The origin of flavor tainting substances is believed to be oil and gas refinery wastes discharged to the Yellowstone River near Laurel and Billings, and heavily chlorinated domestic sewage entering Big Spring Creek from the city of Lewistown.

Methods

Mountain whitefish were taken from the Yellowstone River while rainbow trout were collected from Big Spring Creek. Fish were collected both upstream of and downstream from the suspected source of contamination, including upstream from Laurel, below the Laurel refinery and below the Exxon refinery downstream of Billings. Electrofishing equipment was used to secure fish which were filleted soon after collection, placed in plastic bags, and frozen. Frozen samples were shipped for flavor testing to the Department of Food Science and Technology, Oregon State University. Once the samples reached Oregon State University, they were frozen at -10°F and stored.

In preparation for a test, fish samples were thawed, washed, placed on broiler pans, and covered with aluminum foil. Samples were then cooked for 30 minutes at 400°F in a commercial style gas oven. After cooking, one to two ounce lightly flaked portions were served randomly to a panel of judges in coded paper cups.

Twenty judges were employed during a test; each judge received a labeled control or reference sample and coded cups for each of the test samples (including a blind control). Judges were asked to score the samples on the basis of aroma, texture and flavor (only flavor in the Big Spring Creek samples). A scale of one to nine was used to score samples (one to seven for Big Spring Creek fish) with one indicating identical to the control and nine indicating extremely different. Coded samples were also graded as to overall desirability with a higher score indicating higher desirability.

Each of the 20 judges performed the test twice; however, the code numbers were changed for the second test, thus the panel members did not know which samples were duplicates. Treatments were compared to the controls using a one way analysis of variance and a least significant difference test.

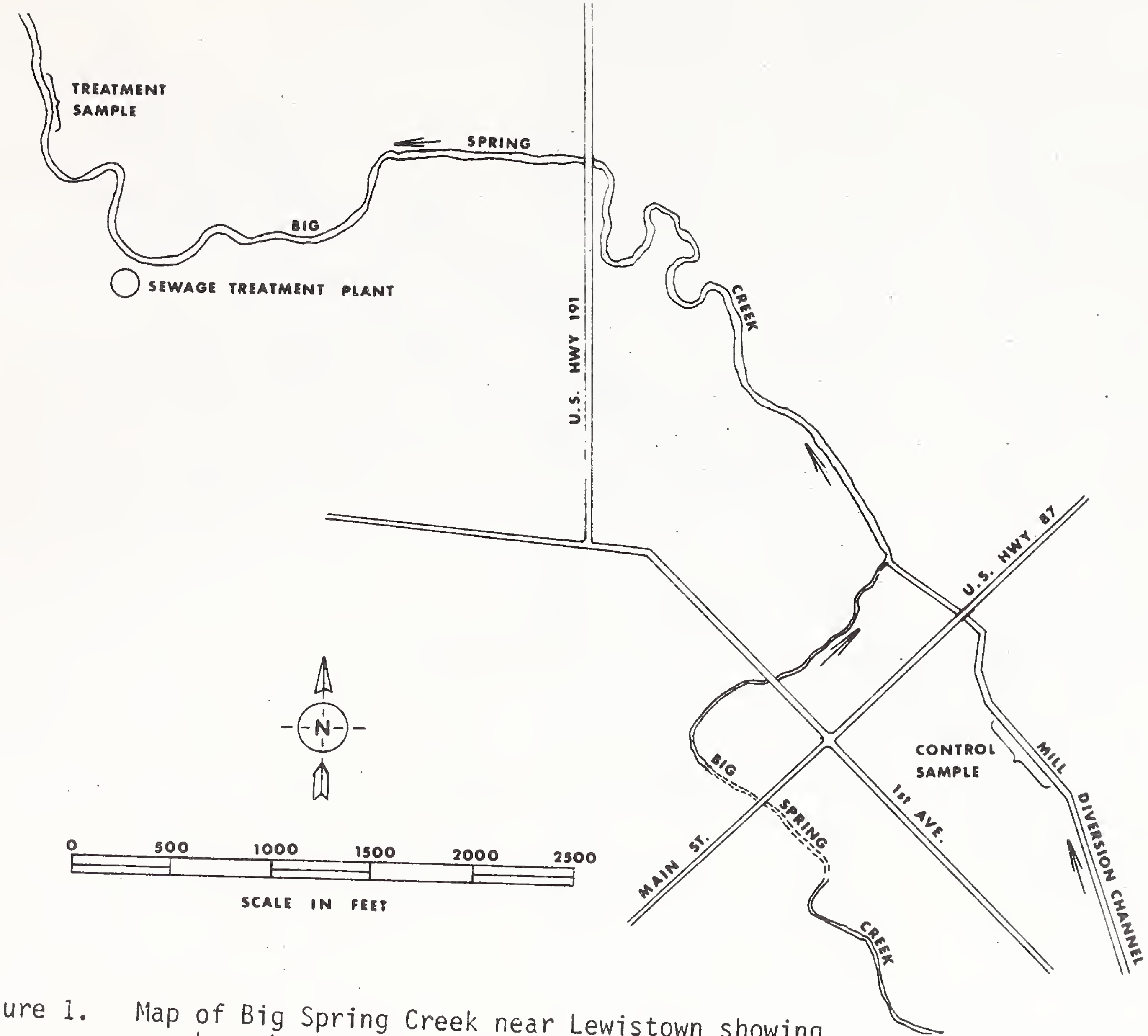

Figure 1. Map of Big Spring Creek near Lewistown showing reaches where fish were sampled for flavor testing.

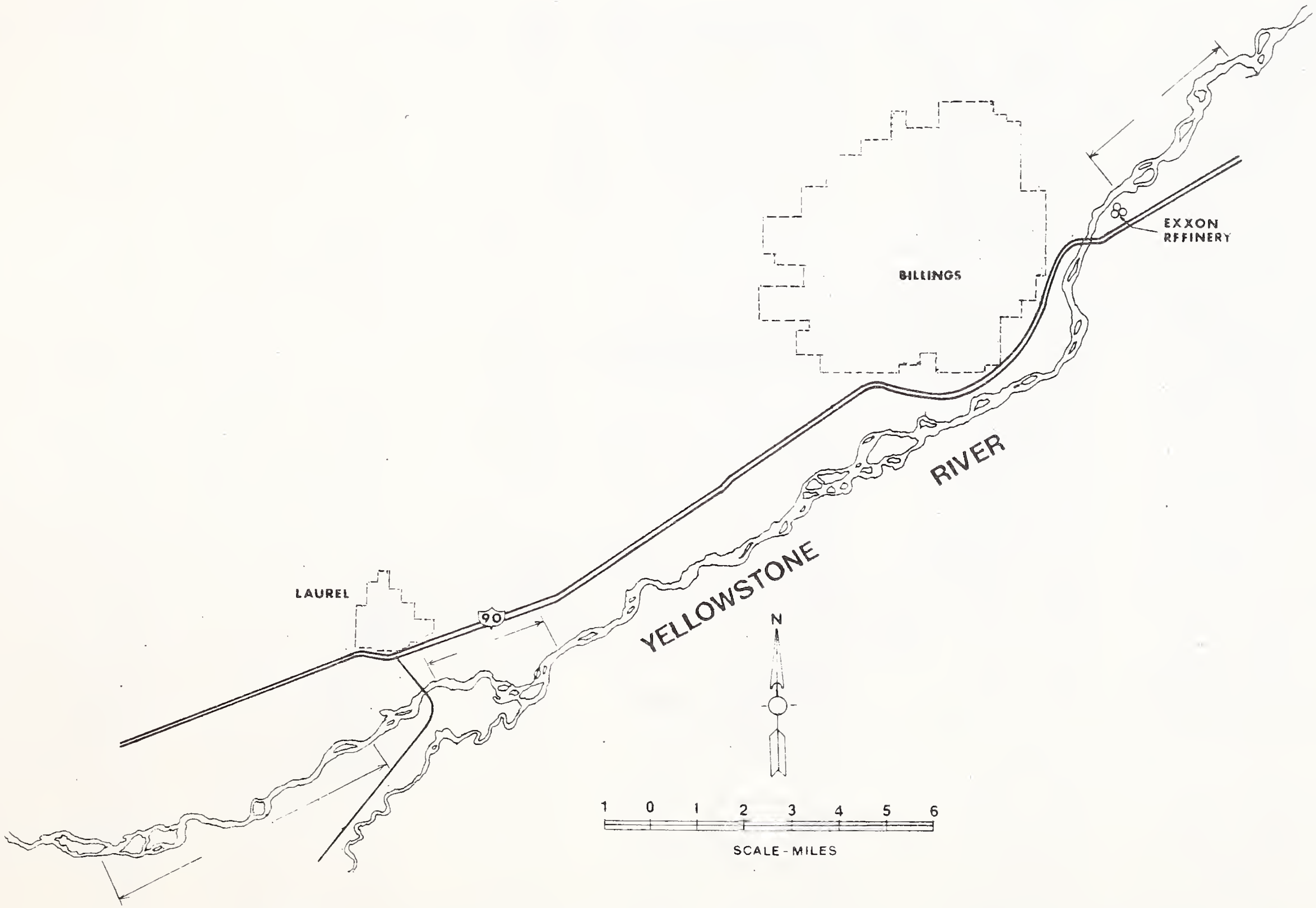

Figure 2. Map of the Yellowstone River in the Laurel-Billings area showing river reaches where fish were sampled for flavor testing.

Results

Fish collected from the Yellowstone River downstream of Billings (below the Exxon refinery) and from Big Spring Creek downstream of the Lewistown sewage treatment plant were judged to be significantly off-flavored and over-all less desirable than fish taken from control sites located farther upstream (Tables 1 and 2). The appearance and texture of the flesh was also rated significantly less desirable in the case of the downstream Yellowstone River fish. Fish taken from the Yellowstone River downstream of the refinery at Laurel were also judged less desirable than controls on the basis of appearance, texture, flavor and over-all desirability. However, the differences were not statistically significant ($p \geq 0.05$).

Degree of off-flavor appears to worsen as you move downstream from Laurel through the industrialized waterfront of Billings. These tests do not identify the source of the off-flavor but refinery wastes are highly suspect. Tests should be conducted in the future to determine if actual discharge water from Exxon or from seeps originating in the area cause off-flavor in fish flesh.

Lewistown sewage receives only primary treatment and thus requires heavier chlorination than more advanced treatment systems. Chlorinated organic compounds formed when chlorine is added to sewage have caused off-flavor in fish from other locations (Shumway and Palensky 1973). The Lewistown treatment facility will be improved and upgraded in the near future. These improvements will greatly decrease the chlorination requirements. Flavor tests should be repeated once the new facility becomes operational.

Table 1. Results of flavor tests using mountain whitefish from the Yellowstone River. Each number is the mean score of 40 judgements by panel members. We submitted unlabeled duplicates of each sample as a cross-check for repeatability. A star (*) indicates that the result is significantly different from the control at the 95% confidence level.

Sample location and description	Parameter [a]			Over-all desirability [b]
	appearance	texture	flavor	
Yellowstone River upstream from Laurel (blind control)	2.27	1.75	2.47	4.60
Yellowstone River downstream from Laurel	2.87* 2.67	2.20 1.92	2.87 2.72	4.27 4.47
Yellowstone River downstream from the Exxon Refinery at Billings	3.30* 3.30*	2.17 2.45*	3.20* 3.27*	4.10* 3.95*

[a] Scores may range from one to nine with one indicating identical to a labeled reference standard and nine indicating extremely different.

[b] Scores may range from one to nine with one indicating extremely undesirable and nine indicating extremely desirable.

Table 2. Results of flavor tests using rainbow trout from Big Spring Creek near Lewistown. Each number is the mean score of 40 judgements by panel members. A star (*) indicates that the result is significantly different from the control at the 99% confidence level.

Sample location and description	Flavor [a]	Over-all desirability [b]
Upstream from Lewistown sewage treatment plant (control)	1.56*	4.31*
Downstream from Lewistown sewage treatment plant	1.88	5.28

[a] Scores may range from 1-7 with one indicating identical to a labeled reference standard and seven indicating extremely different.

[b] Scores may range from one to seven with one indicating extremely undesirable and seven indicating extremely desirable.

Madison River - Transit Times

The high water temperatures that occur in the Madison River downstream of Ennis Reservoir have been a major concern in Montana. To address this problem, the Madison River thermal study was funded by the Montana Legislature to evaluate various options for lowering the water temperature in the reach of the Madison River downstream of Ennis Lake. As part of that study, a thermal model for the river and the reservoir was completed (Goodman 1983). This model required use of a number of assumptions including some regarding flow, or transit, times for various river reaches. Transit time is an important parameter in the model because of its relationship to heat accrual and loss rates.

To eliminate the need for assumptions regarding transit time, we measured transit times for several river reaches, including Kelly Ranch to McAtee Bridge, McAtee Bridge to Varney Bridge, Varney bridge to Ennis Bridge, Ennis Bridge to Valley Garden fishing access site (just upstream from Ennis Lake), Powerhouse to Norris Bridge, Norris Bridge to Grey Cliffs, and Elk Creek to Three Forks (Fig. 3). Transit times were measured at two different flow rates for the reaches ending at Norris and at Grey Cliffs.

Methods

All measurements of flow time were made using current United States Geological Survey techniques (USGS 1982). Rhodamine WT dye was added to the river (as near as possible to the center of the channel) at the upstream end of a reach. Rhodamine is a fluorescent orange color and prior to dispersal, turns the river fluorescent orange. To avoid alarming the public, dye was added to the river before daybreak.

The dye gradually becomes invisible as it disperses and becomes increasingly diluted; consequently, a fluorometer, powered by a portable generator, was used to detect dye in the field. Fluorometric readings were made at 3-5 minute intervals during the period when the dye was passing. Finally, fluorometer reading vs. time was plotted on graph paper, the curve was fitted by eye, and the peak time determined.

Results

Transit time for the various reaches are listed in Table 3 and graphs of peak dye readings are shown in Figures 5 - 13. Note that the river speed at a given flow was much less for the Beartrap Canyon section (Powerhouse to Norris) than for other river reaches with similar gradients. This reach differs from the others in that it is much deeper and has a more restricted and stable channel.

These data were useful because the only previous measurements of flow time were in the Beartrap section. Transit times for the Beartrap section were being erroneously used in the model to estimate flow times for other river sections thereby introducing error into the Madison River thermal model. If additional data is gathered at some future date to refine the model, flow transit time measurements should also be conducted at medium and high flows above Ennis Lake and at high flows below Ennis Lake.

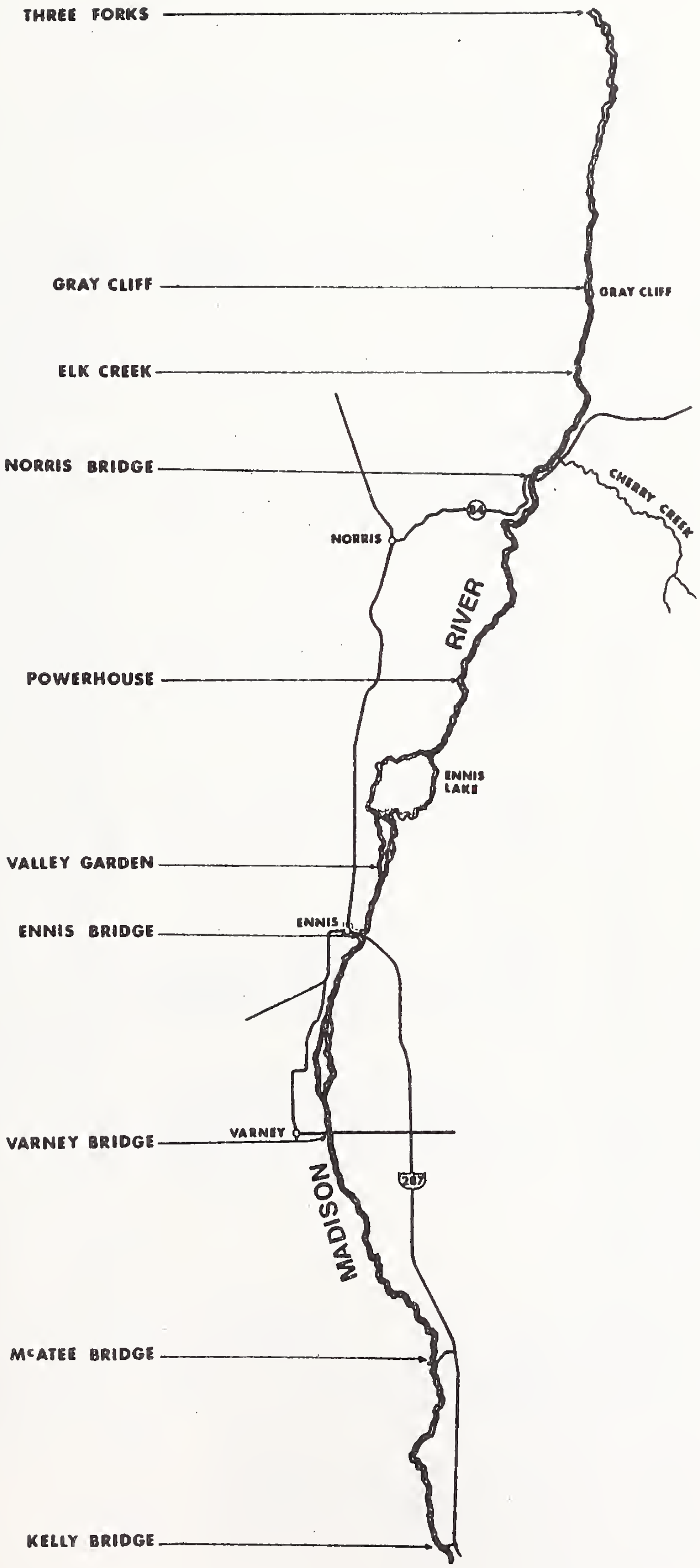

Figure 3. Map of the Madison River showing reaches over which transit time measurements were made.

Table 3. Transit time measurements and calculated river speeds for various reaches of the Madison River, reach length, elevation change, gradient, and discharge rate are also shown.

Reach	Date	Discharge rate (cfs)	Distance (mi)	Elevation change (ft)	Gradient (ft/mi)	Transit time (hrs)	River speed (mph)
Kelly - McAtee	4/21/83	1400[b]	10.3	240	23.3	3.58	2.88
McAtee - Varney	4/21/83	1400[b]	12.2	300	24.5	4.17	2.93
Varney - Ennis	4/21/83	1400[b]	9.1	210	23.1	3.67	2.48
Ennis - Valley Garden	4/21/83	1400[b]	2.4	60	25.0	1.08	2.59
Powerhouse - Norris	4/13/83 4/20/83	1240 1710	10.9	240	22.0	6.00 5.58	1.82 1.95
Norris - Grey Cliffs	4/13/83 4/20/83	1290[c] 1760[c]	8.5	160	18.8	4.08 3.50	2.08 2.43
Elk Creek [a] - Three Forks	5/13/83	1912[c]	19.8	340	17.2	7.95	2.49

[a]Dye added 0.3 miles below the confluence of Elk Creek with the Madison River.

[b]Discharge reading taken at Varney; there are errors associated with these readings due to irrigation withdrawals and entrance of small tributaries; however, these errors should be less than 10%.

[c]Discharge estimates obtained by adding 50 cfs to the reading at the Powerhouse.

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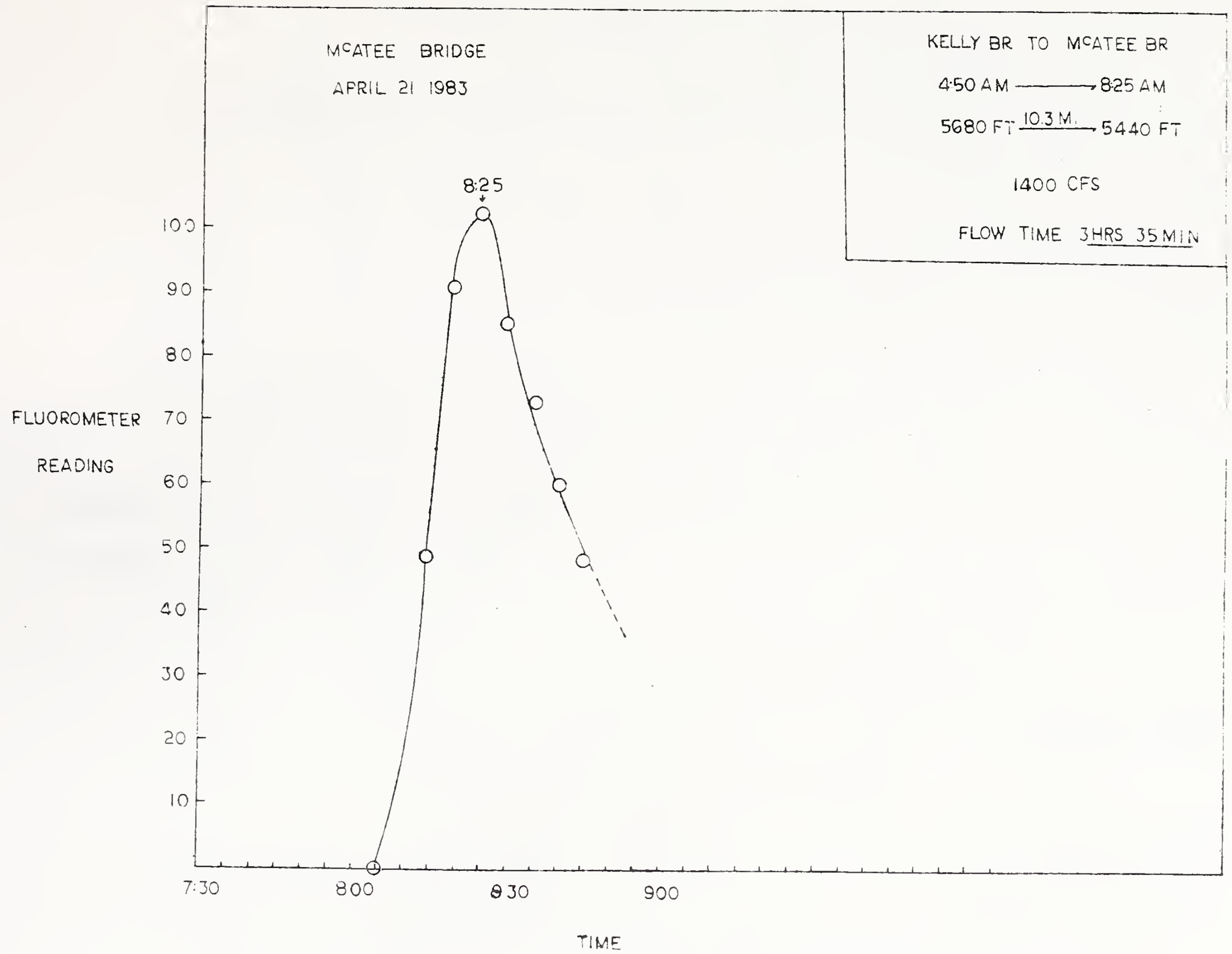

Figure 5. Fluorometric peaks of rhodamine dye recorded in the Madison River during flow transit time measurement in the river reach between Kelly Bridge and McAtee Bridge.

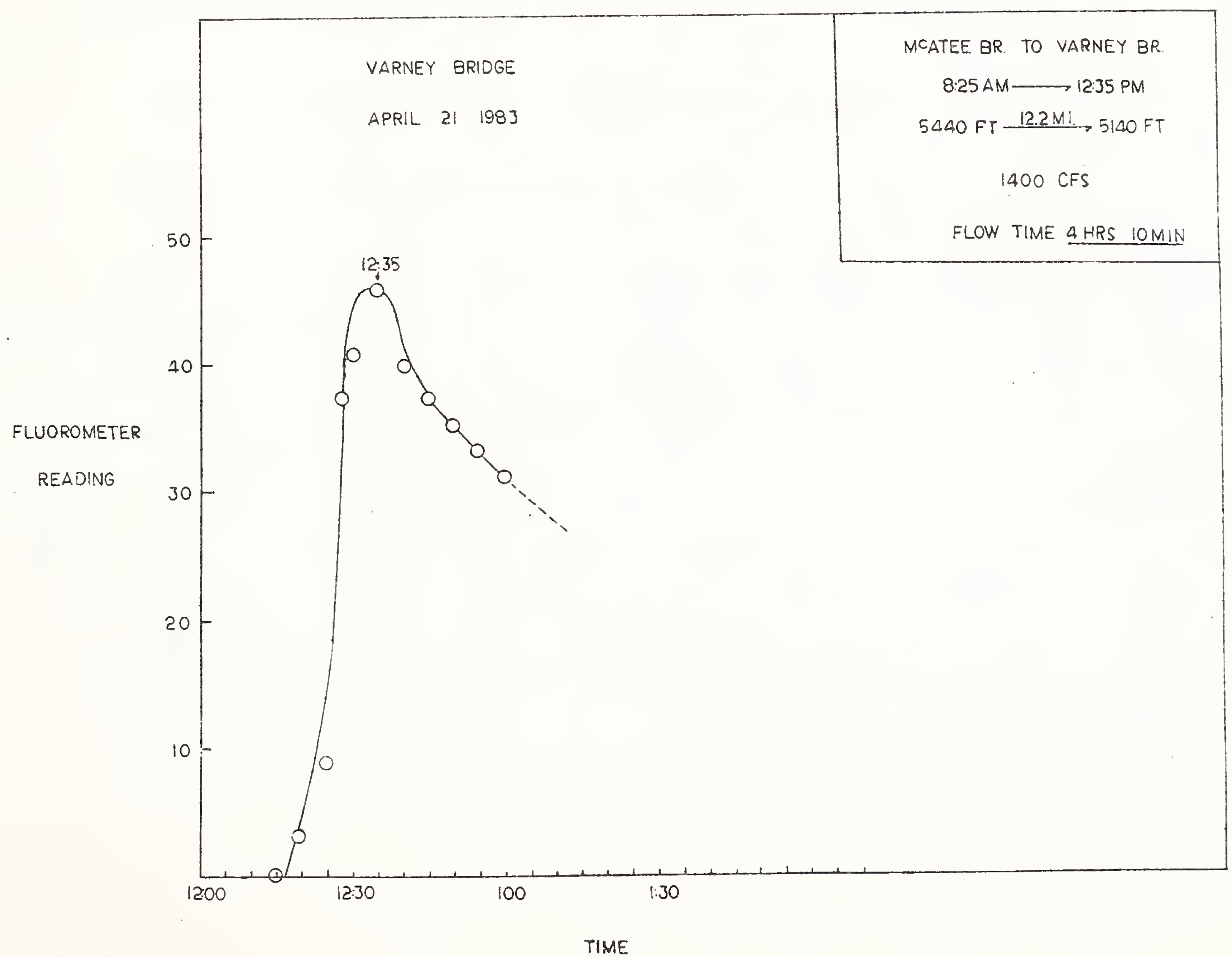

Figure 6. Fluorometric peaks of rhodamine dye recorded in the Madison River during flow transit time measurement in the river reach between McAtee Bridge and Varney Bridge.

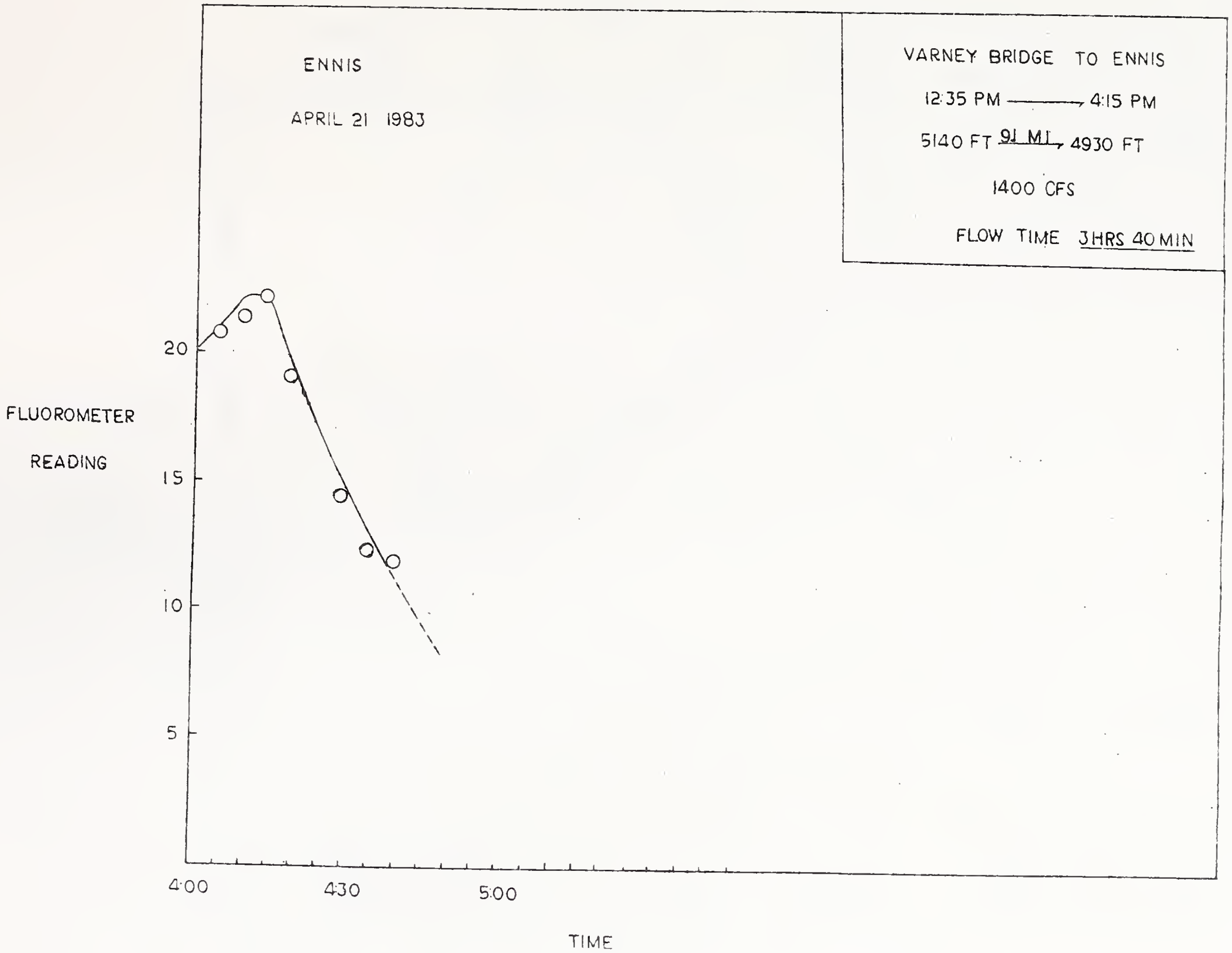

Figure 7. Fluorometric peaks of rhodamine dye recorded in the Madison River during flow transit time measurement in the river reach between Varney Bridge and Ennis.

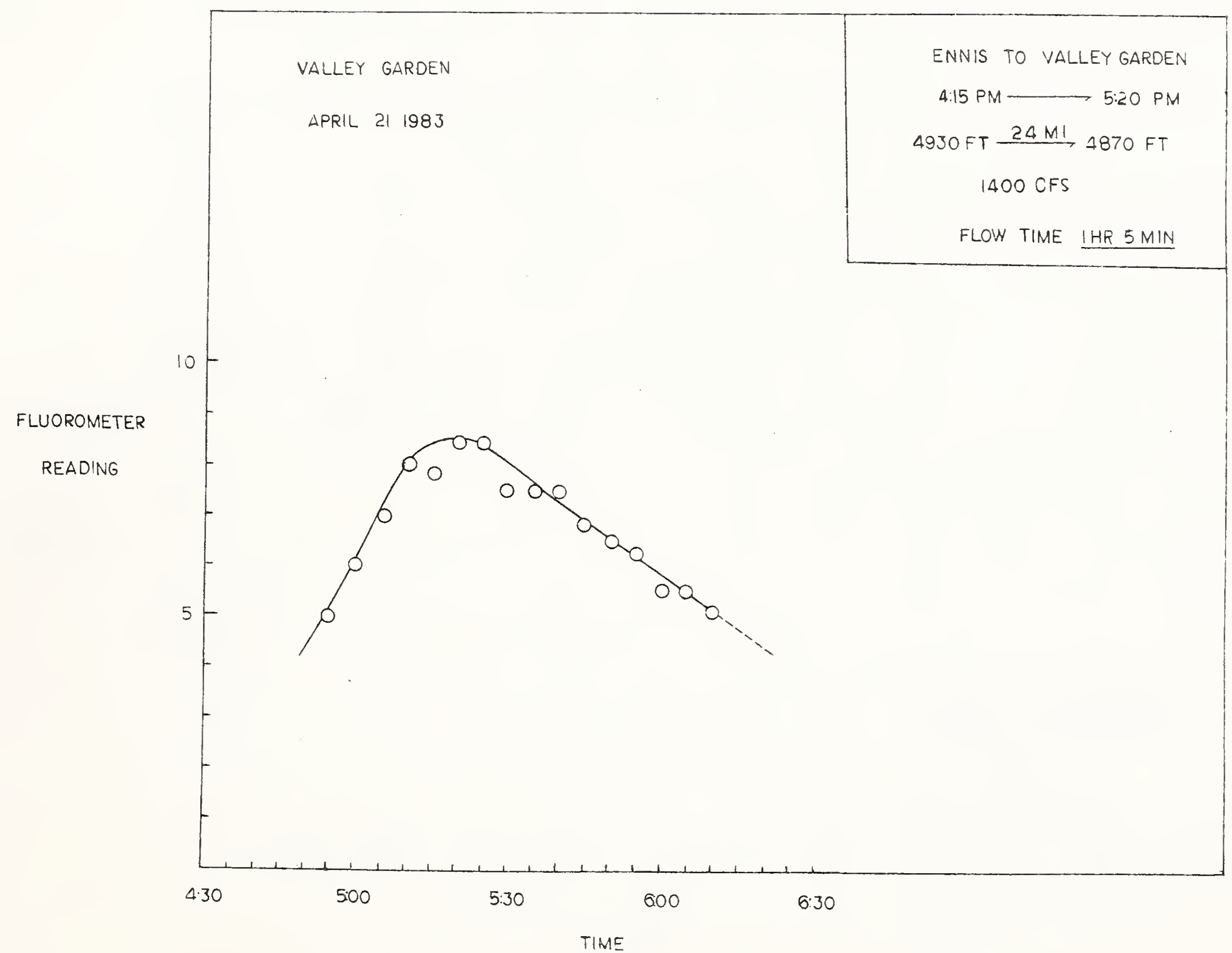

Figure 8. Fluorometric peaks of rhodamine dye recorded in the Madison River during flow transit time measurements in the river reach between Ennis and Valley Garden Fishing Access Site.

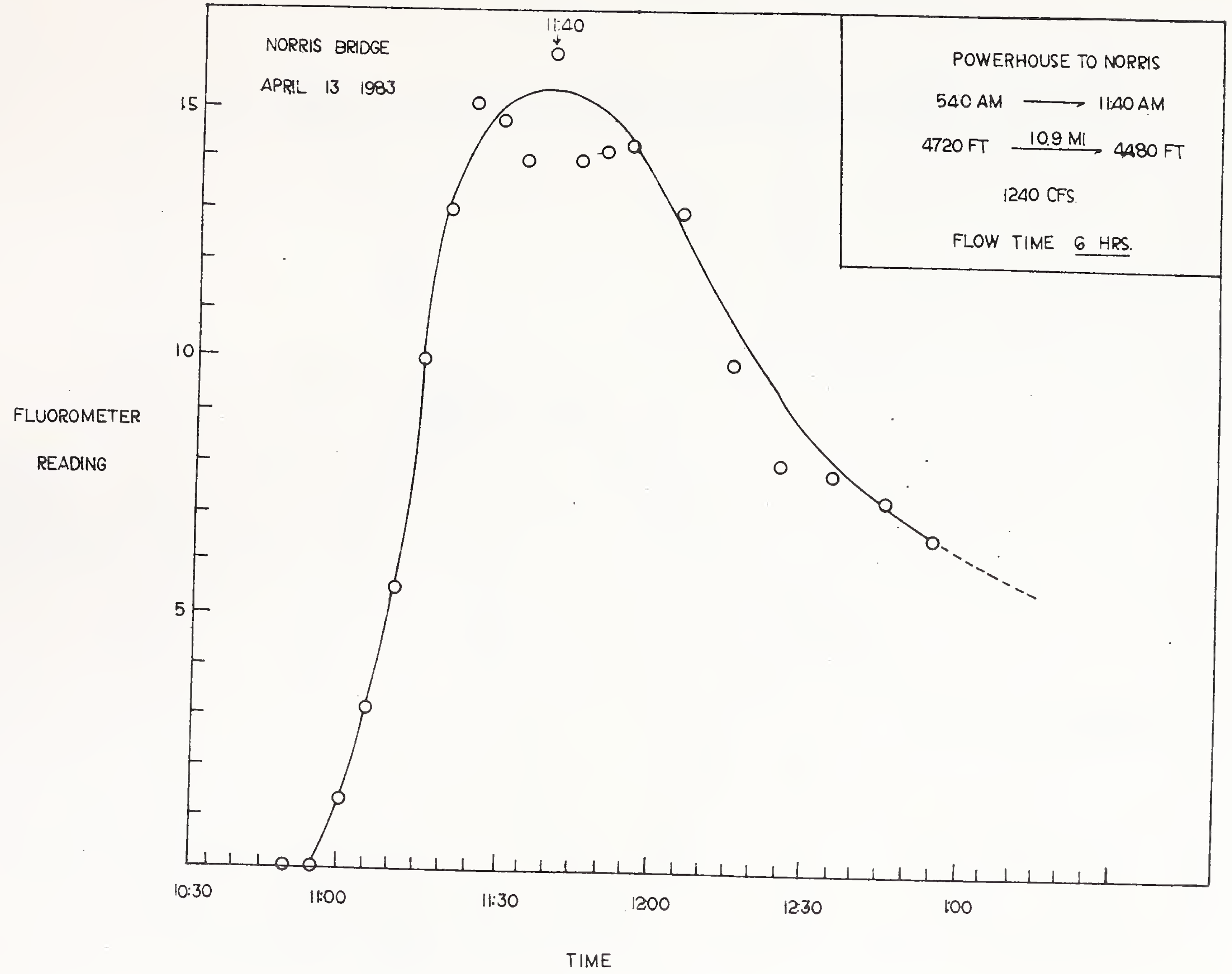

Figure 9. Fluorometric peaks of rhodamine dye recorded in the Madison River during flow transit time measurements in the river reach between the powerhouse below Ennis Lake and Norris Bridge (low flow).

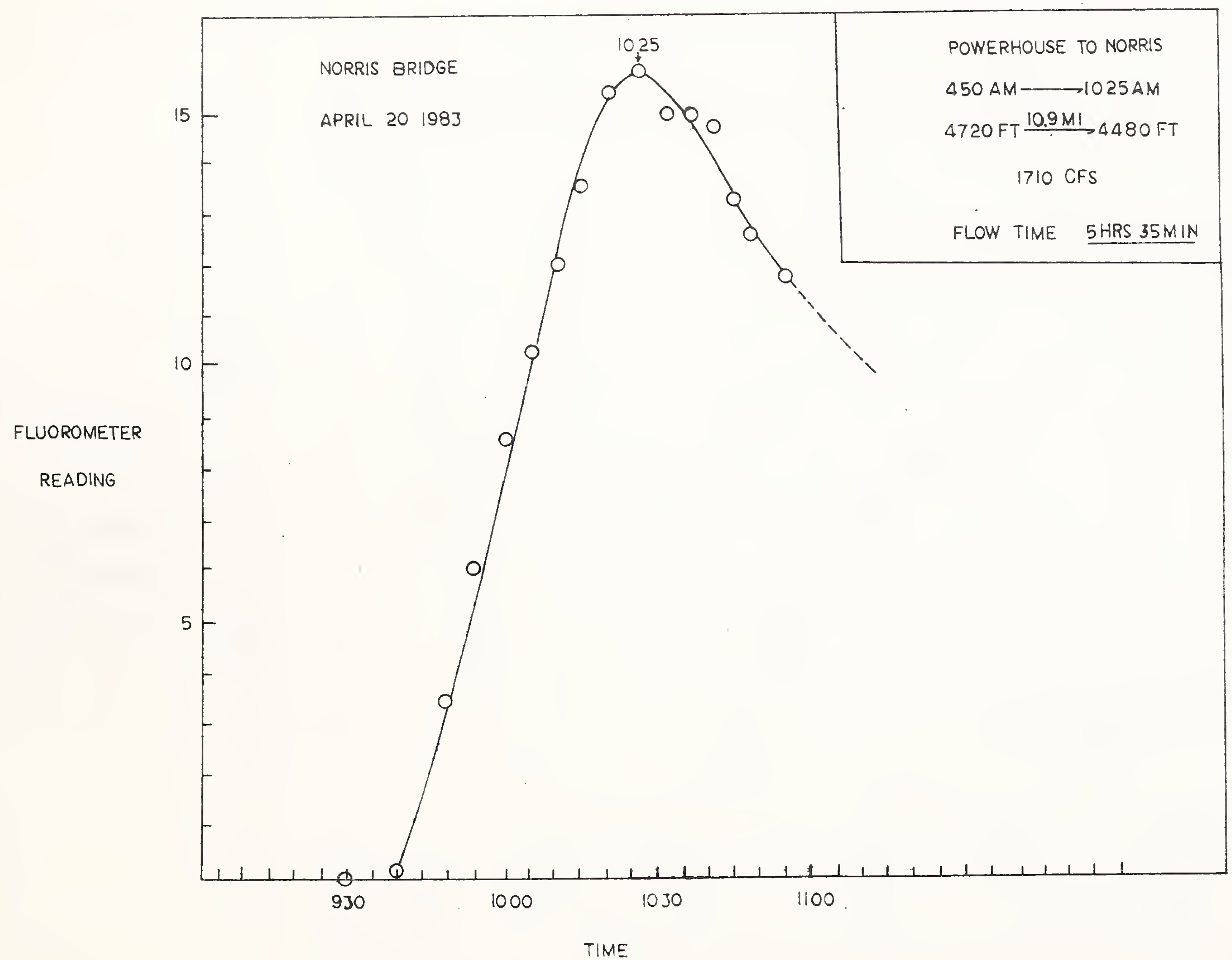

Figure 10. Fluorometric peaks of rhodamine dye recorded in the Madison River during flow transit time measurements in the river reach between the powerhouse below Ennis Lake and Norris Bridge (medium flow).

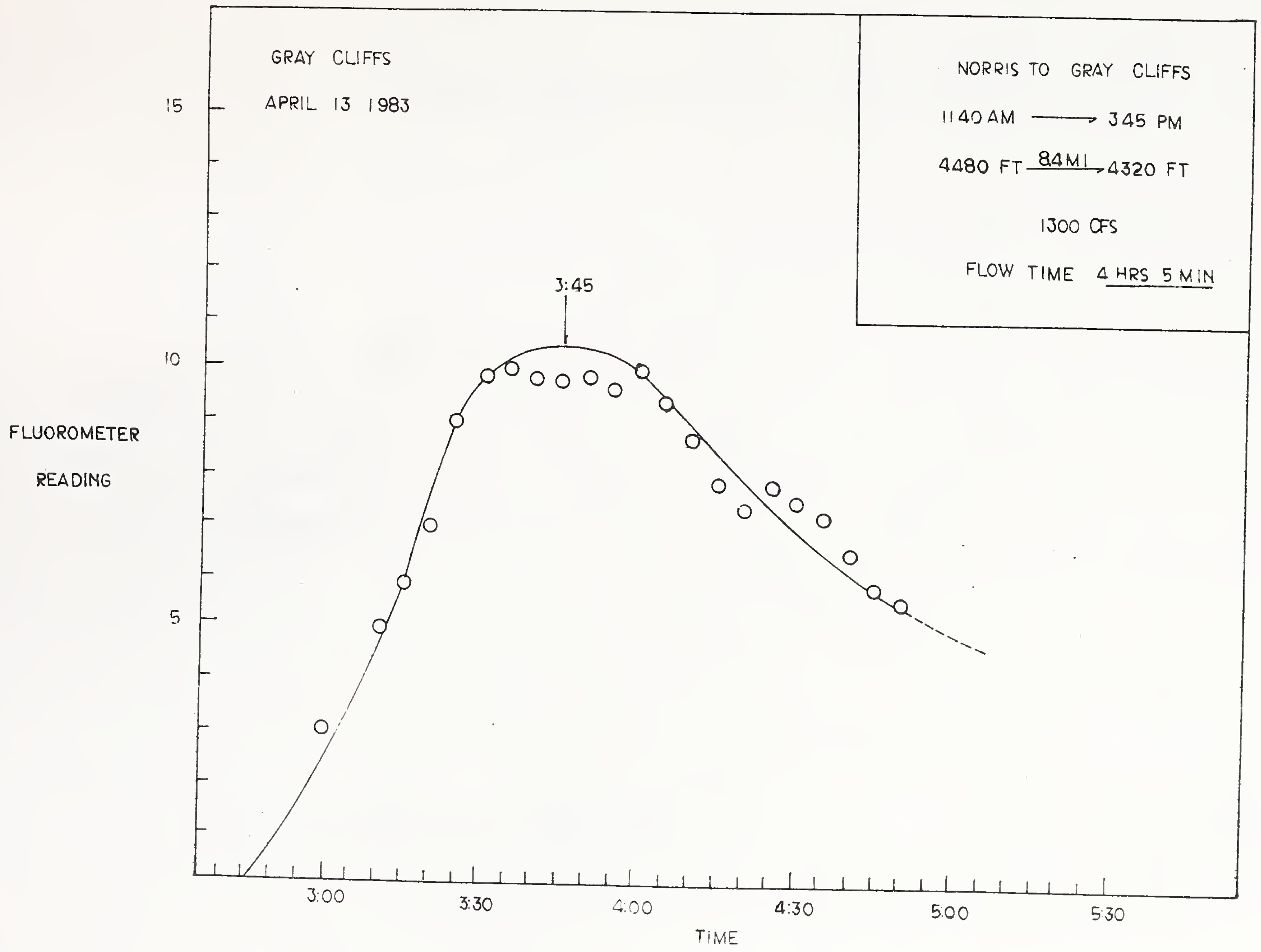

Figure 11. Fluorometric peaks of rhodamine dye recorded in the Madison River during flow transit time measurements in the river reach between the Norris Bridge and Gray Cliffs (low flow).

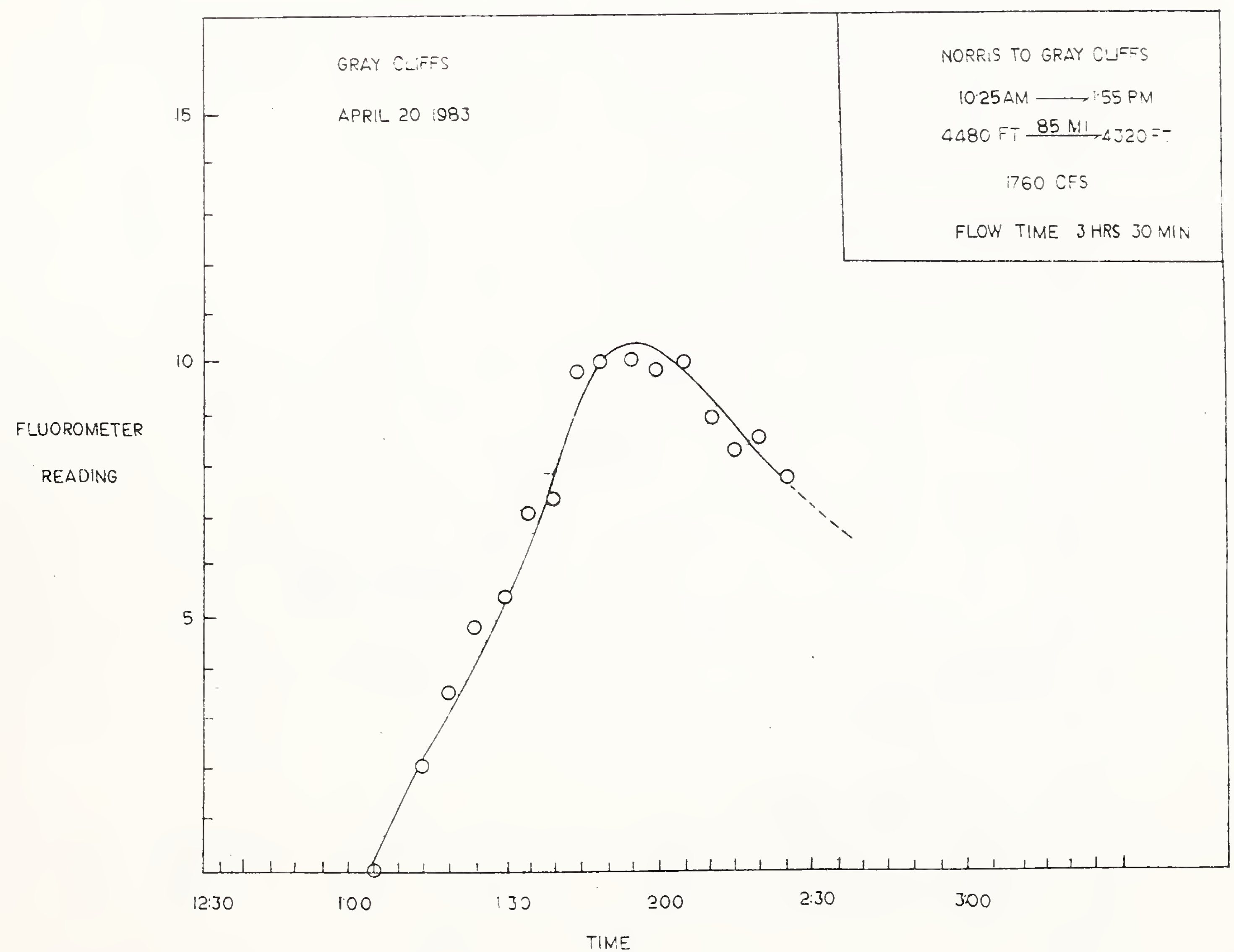

Figure 12. Fluorometric peaks of rhodamine dye recorded in the Madison River during flow transit time measurements in the river reach between the Norris Bridge and Gray Cliffs (medium flow).

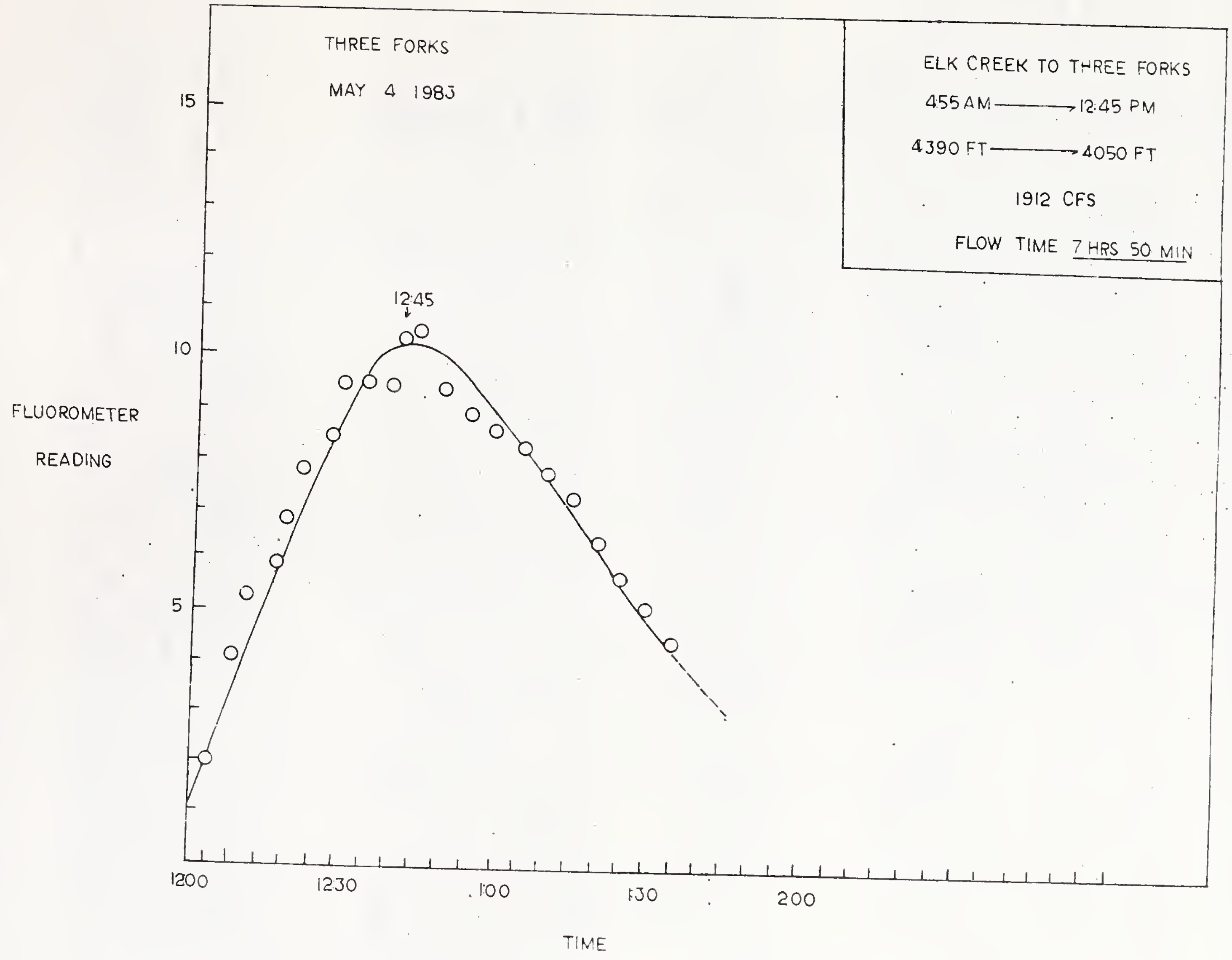

Figure 13. Fluorometric peaks of rhodamine dye recorded in the Madison River during flow transit time measurements in the river reach between Elk Creek and Three Forks.

Madison River - Gonadal Development and Food Habits of Brown Trout Collected Above and Below Ennis Lake

The effect of the reservoir on the thermal regime of the lower Madison River has recently been modeled (Goodman 1983). Mean and maximum daily water temperatures in the stretch of the Madison River below Ennis Lake are considerably higher than those in the reach above the lake. The short retention time in the reservoir combined with the shallow conditions cause the water to warm until it is in equilibrium with the atmosphere.

According to Dick Vincent, long-time fishery biologist on the Madison, brown trout numbers appear to be declining below Ennis Lake. Vincent hypothesized that brown trout reproduction could be failing because the warmer summer water temperatures may hinder the development of gonadal tissue. Accordingly, in cooperation with Dr. Cal Kaya at Montana State University, we monitored gonadal development in brown trout taken from above and below Ennis Lake. Since fish were already being collected and sacrificed, we took advantage of the opportunity to compare food habits of brown trout from the two locations. Temperature differences affect metabolism and feeding activity of fish and may alter food preference or even the kinds of food organisms available.

Methods

Fish were taken from above Ennis Lake on July 20, September 7, and October 14, 1982 and from below the lake on July 21, September 1, and October 13, 1982. Between 8 and 15 fish were taken from each location on each date and these ranged from 278 - 455 mm in length (only one individual was less than 325 mm long).

Fish were collected with standard electrofishing gear, weighed, measured, killed, and placed on ice to slow the digestion of food items present in the stomach. Within 24 h, testes or ovaries were removed and weighed and stomachs were removed and preserved in ethanol. Stomachs were slit to allow the preservative to enter the lumen of the stomach. At a later date contents of the stomach were removed, placed in an enamel pan, and each food type was separated and identified; volume of each food type was then collectively measured by displacement of water.

Results

The rate of ovarian or testicular development was not substantially different (Students t-test) for the two sampling areas (Fig. 14). The onset of gonadal development appeared to be somewhat sooner in the warmer water section, but again the differences were not statistically significant. This was not a particularly severe summer with respect to temperature. Development may be impaired during severe summers but not during others. Tests should be repeated, at least during September and October, following a summer of high summer temperatures.

Food habits of brown trout were noticeably different above the dam than below (Figures 15 - 16). During July, fish above the dam fed primarily on aquatic insects and snails while those from below were eating mostly crayfish and small fish (predominantly sculpins). Crayfish became an even more important food item below the dam in September, accounting for over 80% of the food

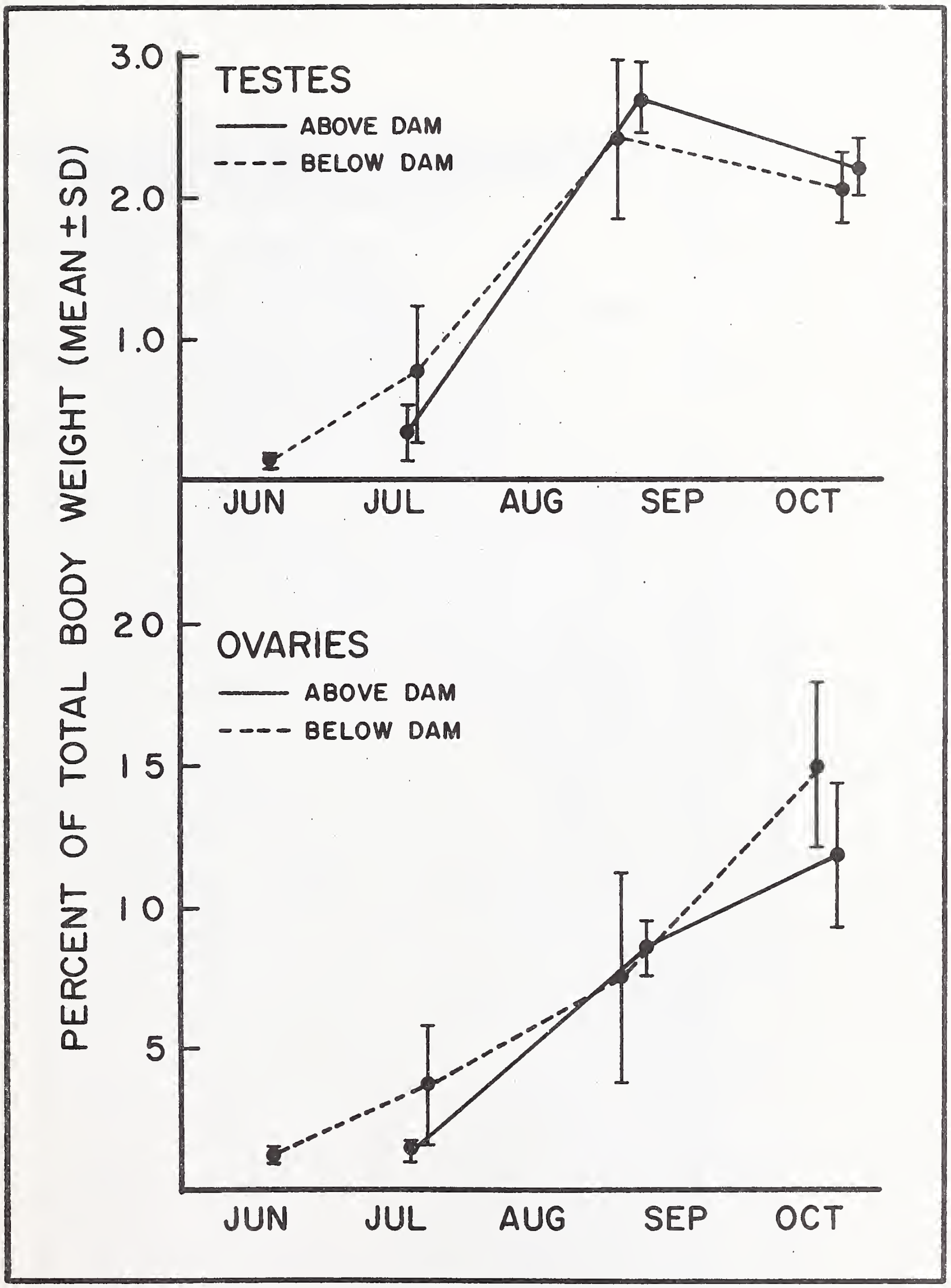

Figure 14. Rates of ovarian and testicular development of Madison River brown trout collected above and below Ennis Dam during the summer of 1982; vertical lines indicate sample ranges.

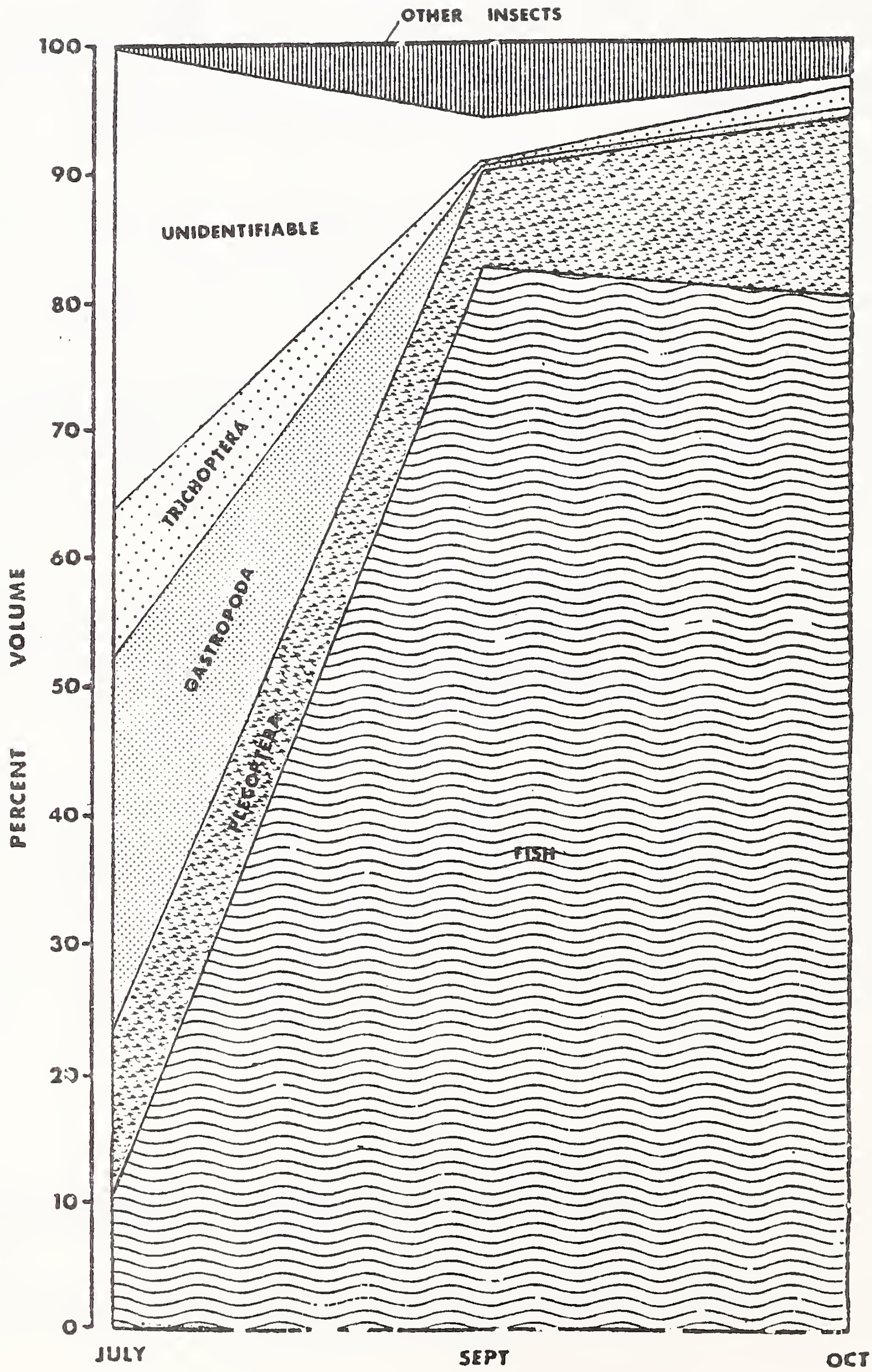

Figure 15. Percentage incidence (by volume) of major food categories present in the stomachs of brown trout taken from the Madison River upstream of Ennis Lake.

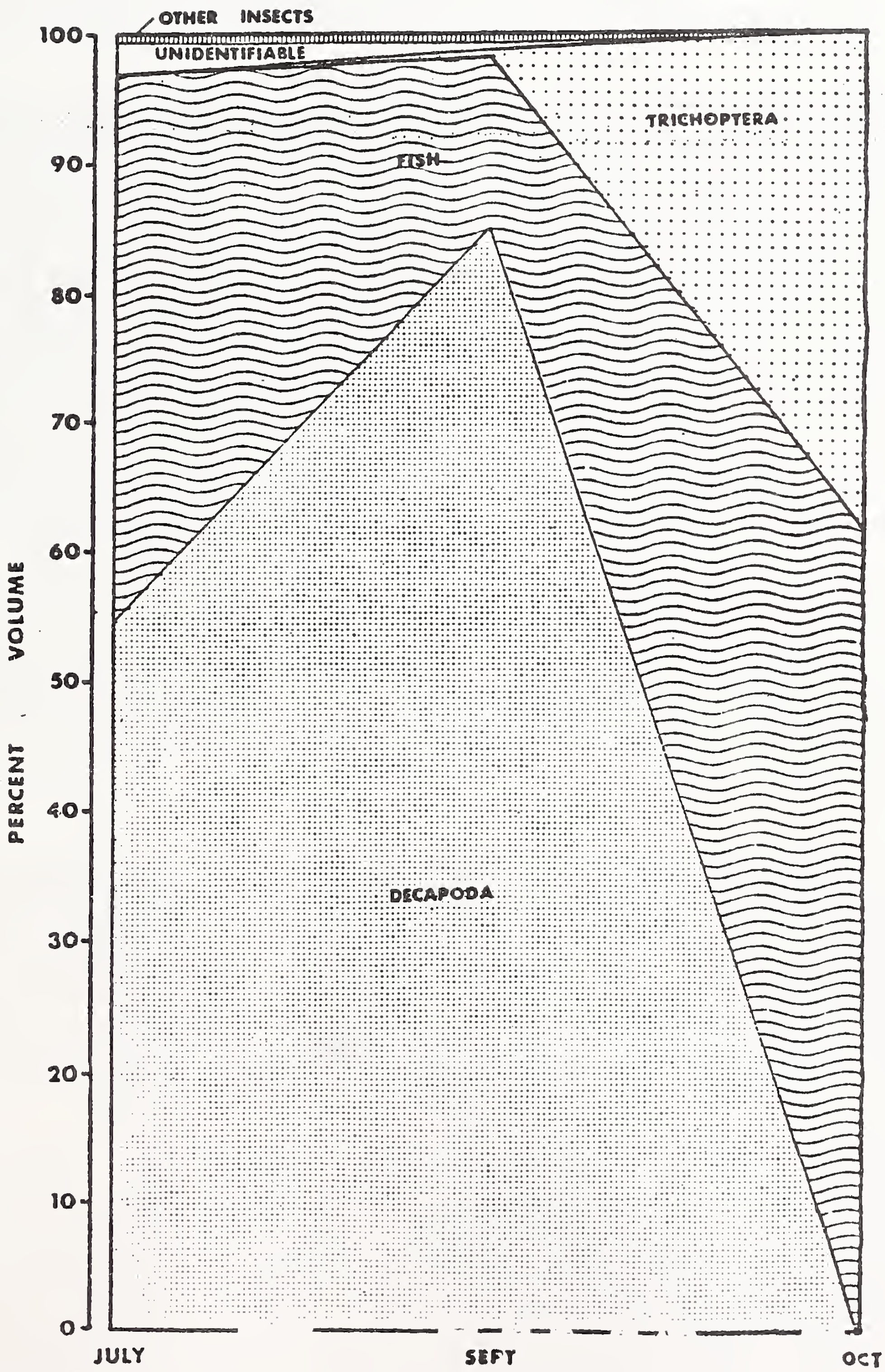

Figure 16. Percentage incidence (by volume) of major food categories present in the stomachs of brown trout taken from the Madison River downstream of Ennis Lake.

present in the stomachs. By comparison, fish became the predominant September dietary item for fish above the dam, representing about 80% of the food consumed. October composition of the diet of fish from above the dam did not change much from that observed in September. However, the diet of brown trout below the dam changed dramatically; crayfish dropped out of the diet while fish accounted for 60% and aquatic insects 40% (predominantly caddis fly larvae).

There has been a great deal of work describing how predator fish select specific types of prey. Ringler (1975) summarized much of the current literature on selective feeding in fish. Several factors have been shown to affect food selection including recognition, nutrition, and energy optimization (energy gained per unit of energy expended). In this study, we did not have data on density of food items to compare to food habits. However, it is clear that the food habits of brown trout from the two locations are markedly different. This is no doubt in part due to physical differences in habitat at the two locations (i.e., the area below the dam is characterized by deeper pools and slower moving water than the are above) but may also be related to temperature differences. A year-long food habit study of brown trout from above and below the dam, combined with information on prey availability, would answer if feeding differences are simply related to prey availability or whether some other ecological variable (such as temperature) is influencing food selection.

Baseline Water Monitoring

We collected baseline water quality information in several locations where large mining operations are planned or have recently begun. These include Lake Creek south of Troy, Grasshopper and Dyce Creeks near Bannack, and German Gulch Creek southwest of Butte.

Monitoring at Lake Creek was initiated to detect possible water quality changes associated with the tailings pond for the ASARCO-Troy project (sampling locations shown in Envirosphere Company, 1981). Monitoring at German Gulch was in response to an open pit gold mine and cyanide milling operation proposed by Montoro Corporation (Fig. 17). Grasshopper and Dyce Creeks are in an area where a huge placer mining operation was proposed by Golden Rule Mining Incorporated. The activity in Grasshopper Creek was proposed near Bannack where the Soil Conservation Service recently completed a reclamation project to isolate mine tailings from the river channel (Fig. 18).

Methods

All water samples were surface grab samples collected in polyethylene bottles. Samples analyzed for nutrients were acidified in the field with 1+1 H_2SO_4; metals samples were acidified with concentrated nitric acid. Hardness, total alkalinity, pH, conductivity and water temperature were measured in the field (except at Lake Creek). Standard procedures were used for all field and laboratory measurements (APHA 1975). Laboratory measurements were performed by the Laboratory Division of the Montana Department of Health and Environmental Sciences using approved Environmental Protection Agency procedures (USEPA 1983). All metals concentrations reported represent the total recoverable fraction.

Results

Grasshopper Creek - Grasshopper Creek below Bannack appears to have recovered from the metals problems that existed there prior to the bank stabilization project completed in the Bannack area in the mid-1970's (Table 4); Dyce Creek also appears to have excellent quality water. Zinc, copper, iron, arsenic and cadmium were present in both creeks at concentrations that meet existing water quality criteria for protection of aquatic life. The water can be categorized as moderately alkaline and moderately hard. Thus, both creeks have some capacity to withstand acid mine drainage and metals toxicity.

Lake Creek - Some changes in Lake Creek water quality were noted in the vicinity of the ASARCO-Troy tailing pond during spring runoff of 1983 (Table 5). During May, total suspended solids concentrations increased from 5 mg/l upstream of the tailing pond, to 14 mg/l adjacent to the pond, to 94 mg/l below the pond. The sprinkler system to control blowing tailing was not installed in the tailing area until the summer of 1983. Prior to that time, wind blown tailing was present on the ground and on vegetation for a considerable distance surrounding the tailing area. Blowing tailing caused residents living downstream of the tailing pond to complain of dust storms. The increase in suspended solids below the ponds may be a result of wind blown tailing entering the stream during spring rain storms or possibly to erosion of unstable bank areas along Lake Creek in the vicinity of the tailing pond.

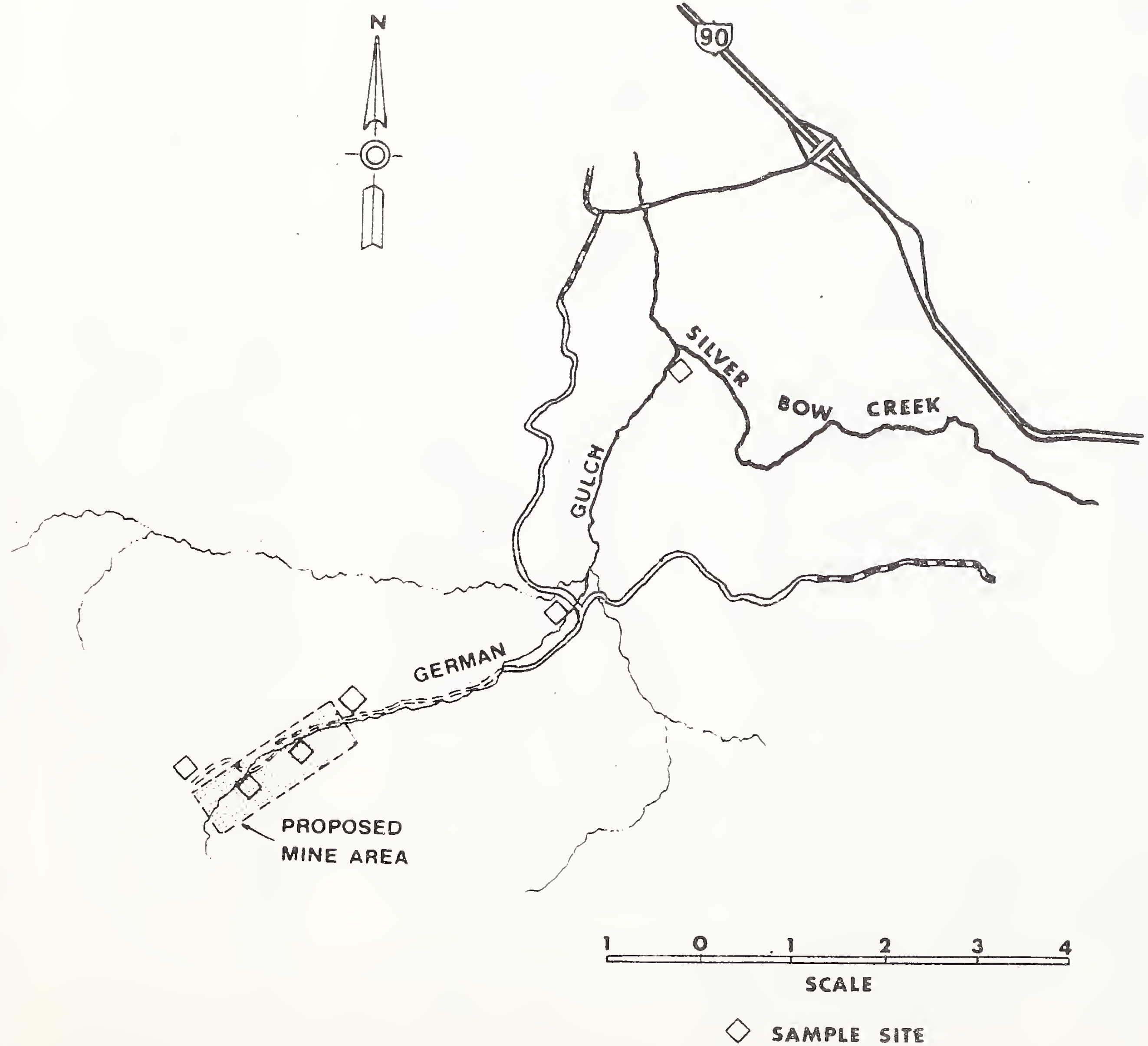

Figure 17. Map of German Gulch Creek showing proposed location of the mill and tailings pond for the Beal Project and water sampling stations (indicated by squares).

Figure 18. Map of Grasshopper and Dyce Creeks showing active placer mines (indicated by triangles) and water sampling stations (indicated by numbers).

Table 4. Summary of various water quality parameters (including means, ranges and standard deviations) in Grasshopper and Dyce Creeks near Dillon, 1982[a].

Parameter	Grasshopper Creek									Dyce Creek					
	Above Bannack			Below Bannack			Mouth			Above mining			Below mining		
	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
pH	8.12	(8.00 - 8.40)	0.15	7.82	(7.60 - 8.15)	0.21	7.88	(7.80 - 7.91)	0.04	8.20	(7.90 - 8.40)	0.22	8.09	(8.00 - 8.20)	0.07
Conductivity (umhos)	172	(101 - 302)	69	236	(172 - 335)	56	212	(123 - 347)	83	181	(110 - 267)	56	278	(165 - 403)	87
Zinc (mg/l)	<0.005	--	--	0.005	(<0.005 - 0.007)	0.001	0.028	(<0.005 - 0.012)	0.046	<0.005	--	--	0.016	(0.005 - 0.050)	0.019
Copper (mg/l)	<0.01	--	--	<0.01	--	--	<0.01	--	--	<0.01	--	--	<0.01	--	--
Iron (mg/l)	0.30	(0.14 - 0.48)	0.12	0.29	(0.15 - 0.43)	0.09	0.028	(0.11 - 0.40)	0.11	0.07	(0.04 - 0.09)	0.02	0.19	(0.03 - 0.35)	0.15
Arsenic (mg/l)	0.002	(0.002 - 0.003)	0.004	0.003	(0.002 - 0.005)	0.001	0.003	(0.002 - 0.005)	0.001	<0.001	--	--	<0.001	--	--
Cadmium (mg/l)	<0.005	--	--	<0.005	--	--	<0.005	--	--	<0.005	--	--	<0.005	--	--
Alkalinity (mg/l as $CaCO_3$)	88	(62 - 103)	15	101	(85 - 120)	12	105	(85 - 120)	16	110	(95 - 120)	11	168	(143 - 188)	16
Hardness (mg/l as $CaCO_3$)	88	(68 - 103)	13	101	(85 - 137)	19	125	(85 - 195)	41	116	(103 - 120)	7	167	(154 - 188)	14
TSS (mg/l)	16.1	(7.3 - 30.5)	8.5	14.5	(7.9 - 30.2)	8.0	37.3	(9.2 - 116.1)	40.0	13.4	(6.8 - 28.2)	8.2	18.1	(8.0 - 24.6)	6.4

[a]Samples were collected on June 30, July 29, August 25, September 29 and November 4, 1982.

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Table 5. Summary of various water quality parameters (including means, range and standard deviation) in Lake Creek during 1983.

Parameter[a,b]	Upstream of tailings			Adjacent to tailings			Downstream of tailings		
	Mean[c]	Range	SD	Mean[c]	Range	SD	Mean[c]	Range	SD
Calcium	7.78	(5.1 - 10.3)	2.18	7.83	(5.4 - 10.5)	2.17	7.95	(5.5 - 10.9)	2.35
Magnesium	1.33	(0.9 - 1.8)	0.38	1.17	(0.7 - 1.6)	0.47	1.23	(0.7 - 1.7)	0.47
Bicarbonate	34.5	(24 - 44)	7.92	35.8	(28 - 44)	6.49	35.0	(27 - 44)	6.28
Sulfate	0.5	--	--	0.5	--	--	0.5	--	--
Nitrate & Nitrite (mg/l as N)	0.13	(0.02 - 0.32)	0.13	0.05	(0.03 - 0.08)	0.02	0.14	(0.03 - 0.30)	0.11
Ammonia (mg/l as N)	--	(<0.01 - 0.03)	--	--	(<0.01 - 0.01)	--	--	0.01	--
Conductivity (umhos)	68.0	(56 - 81)	10.7	67.8	(57 - 81)	10.9	64.7	(55 - 78)	10.1
Hardness (mg/l as $CaCO_3$)	24.8	(17 - 32)	6.8	24.2	(16 - 33)	7.4	25.0	(17 - 34)	7.6
Alkalinity (mg/l as $CaCO_3$)	31.3	(25 - 36)	4.6	29.5	(23 - 36)	5.2	29.5	(23 - 36)	5.2
Turbidity (ntu)	2.9	(1.0 - 8.0)	3.0	2.1	(1.8 - 2.6)	0.29	5.1	(1.0 - 15.0)	5.7
TSS	9.3	(5.1 - 14.4)	3.5	10.4	(6.4 - 13.8)	3.1	29.3	(6.2 - 93.8)	37.3
Zinc	0.017	(<0.005 - 0.04)	--	0.006	(<0.005 - 0.01)	--	0.009	(<0.005 - 0.02)	--
Iron	0.03	(0.02 - 0.04)	--	0.10	(<0.03 - 0.25)	--	0.12	(<0.03 - 0.28)	--
Copper	<0.01	--	--	<0.01	--	--	<0.01	--	--
Silver	<0.01	--	--	<0.01	--	--	<0.01	--	--

[a] All parameters in mg/l unless noted otherwise.

[b] Samples were collected on March 31, April 28, May 27, and June 24.

[c] If concentration was below detection limit, the detection limit was used in calculating the mean value.

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At the same time, iron concentration in Lake Creek increased from 0.02 mg/l above the tailing ponds, to 0.25 mg/l adjacent to the ponds, to 0.20 mg/l below the ponds. This had also occurred in April (although to a lesser degree) when the progression from upstream to downstream was 0.04, 0.07 and 0.12 mg/l. There are at least two iron seeps originating at the base of the bench on which the tailing pond is located. Iron from these seeps may be entering Lake Creek as a result of higher than usual flows during the spring period when both groundwater tables and precipitation are highest. Riechmuth (1984) in a recent report resulting from an inspection of the tailing area expressed concern over the stability of the tailing structure in the area of these seeps. The validity of this concern is presently being explored by the Montana Department of State Lands.

The concentration of nitrate plus nitrite nitrogen was higher above the pond (0.32 mg/l as N) than below (0.10 mg/l as N). There is no ready explanation for this. ASARCO has detected high concentrations of nitrogen compounds in Stanley Creek during their monitoring. Blasting compounds used in the mine are high in nitrogen; the possibility that these compounds are entering Lake Creek via Stanley Creek should be explored further.

Other water quality parameters were present in Lake Creek at concentrations that are indicative of good quality water. However, it should be noted that the stream is naturally low in alkalinity and hardness, and thus is highly susceptible to acid mine drainage and metals pollution if it were to occur.

German Gulch Creek - The quality of water in German Gulch Creek is good; metals and common ions exist within a healthy range (Table 6). Water entering the head of German Gulch from an historic mine adit is also of good quality with no indication of acid waters. Nevertheless, German Gulch Creek is naturally low in alkalinity and hardness and as such is susceptible to acid inputs.

Table 6. Results of baseline water monitoring in German Gulch Creek.

	November 15, 1983					February 2, 1984			
Parameter	Above adit	Adit discharge	Above proposed dam site	Below proposed dam site	Near Norton Creek	Above proposed dam site	Below proposed dam site	Near Norton Creek	Near mouth
Calcium (mg/l)	14.8	43.7	27.1	25.9	17.2	27.7	26.0	31.0	33.6
Magnesium (mg/l)	1.0	7.4	2.5	3.0	2.3	2.7	3.4	6.0	7.1
Sodium (mg/l)	2.0	6.0	3.0	3.0	3.0	2.5	2.7	3.3	4.4
Potassium (mg/l)	0.7	1.6	1.1	1.7	1.8	1.3	1.9	2.1	1.8
Chloride (mg/l)	0.9	2.6	1.7	1.3	1.1	1.2	1.2	1.2	1.6
Sulfate (mg/l)	8	71	26	25	17	26	24	16	11
Hardness (mg/l as $CaCO_3$)	106	106	78	70	62	80	79	102	113
Alkalinity (mg/l as $CaCO_3$)	40	40	50	60	46	60	62	52	98
pH	7.13	7.12	7.12	6.74	7.15	6.80	6.95	7.30	7.45
Copper (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zinc (mg/l)	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Lead (mg/l)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (mg/l)	0.13	0.04	0.06	0.01	0.02	--	--	--	--
Cadmium (mg/l)	--	--	--	--	--	0.005	0.005	0.005	0.005

Metals Residues in Fish Tissue and Sediments

Mercury concentrations were determined in the edible tissues of fish from a number of locations including Grasshopper Creek and the Beaverhead River southwest of Dillon, Silver Creek north of Helena, Crow Creek south of Helena, and Fred Burr Creek south of Philipsburg. These locations were chosen either because fish sampled from these same areas several years earlier were found to contain concentrations of mercury that exceeded action levels established by the Food and Drug Administration (FDA), or because historical reports indicated that mercury had been used in the drainage.

Bottom sediments from Grasshopper Creek were also analyzed for a number of additional metals to allow comparison of present metals concentrations to those that existed prior to the tailing stabilization project completed by the Soil Conservation Service during the mid-1970's. This was a rip-rap project designed to prevent the creek from eroding into old mine tailing deposited on one of its banks.

Methods

Fish were collected from three locations in Grasshopper Creek, two locations in Fred Burr Creek, two locations in Silver Creek, two locations in Crow Creek and one location in the Beaverhead River just downstream of Grasshopper Creek. Standard electrofishing techniques were used to collect fish and stream sediments were sampled by grab.

Metals analyses were completed by the analytical laboratory of the Department of Agriculture in Bozeman. Mercury in tissues was measured with a Varian model AA-6 atomic absorption spectrophotometer using the method of Siemer and Woodriff (1974). Tissue was taken from a dorso-lateral section of a fillet with all skin and bone removed. Results are reported on a wet-tissue basis.

Sediment samples were centrifuged, dried, and metals were extracted in 20% acetic acid. Analysis was by atomic absorption spectrophotometry; results are reported on a dry weight basis.

Results

Grasshopper Creek - All of the brown trout sampled from Grasshopper Creek and from the Beaverhead River downstream of its confluence with Grasshopper Creek had mercury concentrations in muscle tissue (Table 7) that were below the FDA action level (1.0 ug/g wet tissue). The highest concentration found was 0.85 ug/g in a trout taken below Bannack. The average concentration in fish from the Beaverhead River was lower than that in the fish from Grasshopper Creek, suggesting that Grasshopper Creek is still liberating mercury that was historically lost during gold recovery operations. Still, there is no indication that consumption of these fish would be hazardous to humans.

Metal concentrations in sediments have decreased considerably since 1976 (Table 8). Concentrations of copper, zinc, lead, iron and arsenic have all decreased below the Golden Leaf Mill and copper, zinc, lead, cadmium and arsenic have all decreased near the mouth. Metals concentrations in sediments upstream of the mill have also decreased. Zinc, lead and iron were all present at lower concentrations in 1982 than in 1976.

Table 7. Summary of mercury concentrations in trout from several locations in Montana.

Location	Date sampled	Site description	Species trout	Sample size	Fish length (in) Mean	Fish length (in) Range	Mercury conc. (ug/g wet weight) Mean	Mercury conc. (ug/g wet weight) Range
Grasshopper Creek	April, 1983	Hammond ranch	Brown	7	13.8	12.8 - 14.2	0.48	0.38 - 0.64
Grasshopper Creek		below Bannack	Brown	10	14.6	13.6 - 15.5	0.52	0.29 - 0.85
Beaverhead River		below Grasshopper Creek	Brown	10	17.0	15.6 - 18.4	0.31	0.15 - 0.59
Silver Creek	June, 1983	above Buck Lake	Cutthroat	6	11.0	5.8 - 17.0	1.68	0.38 - 4.30
Silver Creek		near Chairman Gulch	Cutthroat	5	7.5	5.4 - 9.9	0.38	0.29 - 0.52
Fred Burr Creek	June, 1983	below Rumsey Mine	Rainbow	7	6.4	5.6 - 7.2	0.76	0.46 - 1.50
Fred Burr Creek		near highway 10A	Brook	9	7.8	5.5 - 10.2	0.27	0.19 - 0.45
Crow Creek	August, 1983	above Crow Creek Falls	Rainbow	6	7.9	6.7 - 9.4	0.14	0.06 - 0.30
Crow Creek		9 mi. below Crow Creek Falls	Brook and Rainbow	6	8.3	7.0 - 9.0	0.08	0.06 - 0.11

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Table 8. Metal concentrations in sediments from Grasshopper Creek before and after stabilization of the mine tailings near Bannack.

Location and year	Metals concentrations in sediment (ug/g)[a]					
	Cu	Zn	Pb	Cd	Fe	As
Upstream from Bannack 1976	17	165	45	0.9	26,510	40
Upstream from Bannack 1982	16	83	24	2.1	13,300	3
Below Golden Leaf Mill 1976	505	375	404	1.5	105,070	220
Below Golden Leaf Mill 1982	24	87	42	2.9	36,974	13
Mouth 1976	215	1,115	1,110	14.0	27,500	166
Mouth 1982	29	87	34	3.1	27,617	10

[a]Concentrations reported on a dry weight basis.

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Invertebrate community changes reflect improved water quality. For two locations downstream of Bannack, Oswald (1983) showed that there have been significant increases in both macroinvertebrate numbers and taxa; however, fish numbers have not increased. The tailing stabilization project at Bannack appears to have been a success and the stream is beginning to recover. At this time, habitat alterations due to past and more recent mining are probably the limiting factor controlling fish numbers.

Silver Creek - Silver Creek in Lewis and Clark County is another drainage where mercury was historically used and lost. The reactivation of old tailing ponds located adjacent to Silver Creek upstream of Buck Lake has apparently aggravated the problem of mercury entering the creek.

Mercury concentrations in muscle tissue of cutthroat trout from Silver Creek were unusually high (Table 7). Three larger trout ranging in length from 12.6-16.5 inches contained 2.1, 2.3 and 4.3 ug Hg/g wet tissue. These are extremely high concentrations (the FDA action level is 1.0 ug Hg/g); therefore both the FDA and local health authorities in Lewis and Clark County were notified. This resulted in a recommendation from Lewis and Clark County to the Fish and Game Commission that Silver Creek be closed to fishing. The Commission ultimately decided to leave the creek open to fishing but voted to restrict the area to catch and release fishing only.

Fred Burr Creek - A third location where mercury residues in fish were examined was Fred Burr Creek southeast of Philipsburg. Miners had historically used mercury at the old mill site near Rumsey.

Rainbow trout collected just downstream of Rumsey averaged 0.76 ug Hg/g (Table 7); one of these exceeded the FDA guidelines and contained 1.50 ug/ Hg/g. Comparatively, rainbow and brook trout taken several miles downstream, near the Highway 10A bridge averaged only 0.27 ug Hg/g. Van Meter (1974) also reported that mercury concentrations in trout tended to decrease downstream of the old mill site. The average concentration of mercury in fish that we sampled was lower than that in fish sampled by Van Meter from approximately the same locations. However, Van Meter did not record the sizes of fish in his sample. This makes the comparison difficult because mercury in fish tends to increase in concentration as fish grow older and larger.

Local health authorities were notified of our findings, however no action was taken. This was not judged to be a serious problem because of the low density and size of fish in the Rumsey area and the relative infrequency with which fish exceeded the FDA guideline.

Crow Creek - Fish were sampled from Crow Creek in response to a request from a local miner who was familiar with the historic use of mercury in the drainage and was concerned about eating the fish. Trout taken from immediately above Crow Creek Falls and from a stream reach approximately 9 miles below the falls averaged 0.14 and 0.08 ug Hg/g, respectively (Table 7). None of the fish sampled approached the FDA guideline (1.0 ug Hg/g); the highest mercury concentration found was 0.30 ug Hg/g in a rainbow trout taken above Crow Creek Falls. No additional action was believed necessary.

Chlorinated Hydrocarbons in Montana Fishes

Concern over residues of pesticides and other hazardous substances that may be present in fish and wildlife has escalated in Montana due to recent findings concerning endrin (Schladweiler and Weigand 1983). Unfortunately, very little information is available on concentrations of chlorinated hydrocarbons in tissues of Montana fishes. In response to this concern, fish were collected from a number of locations in Montana during 1982 and 1983 to determine concentrations present of a number of chlorinated hydrocarbon residues.

Fish were collected below hydroelectric facilities where electrical transformers may be insulated with PCB's, near areas where PCB spills have occurred, or downstream of major industrial communities where PCB usage is common. All of the rivers sampled also drain major agricultural centers where pesticide usage is common.

Sites included the Madison River below Hebgen and Ennis Dams; the Missouri River below Canyon Ferry, Holter, and Fort Peck Dams; the Marias River near Moffat; the Boulder River below the town of Boulder; and Big Spring Creek downstream of Lewistown.

Methods

Residues sampled for included DDT and its metabolites DDD and DDE, polychlorinated biphenyls, dieldrin, benzene hexachloride, lindane, hexachlorobenzene, endrin, and heptachlor epoxide.

Fish were collected by electrofishing, weighed, measured, wrapped in aluminum foil, placed in plastic bags and stored on ice. Upon return to the laboratory, fish were filleted and the tissue was wrapped in aluminum foil, labeled and frozen. Frozen fillets were shipped on dry ice by air freight to Hazleton Raltech Laboratories in Madison, Wisconsin where the residue analyses were performed.

At Hazleton Raltech, fish tissue samples were ground and blended with methyl cyanide. Chlorinated hydrocarbons were partitioned into petroleum ether, dried over anhydrous Na_2SO_4, and eluted through a florisil column with 15% ethyl ether to petroleum ether (volume/volume). Finally, residues were quantified using a gas chromatograph equipped with an electron capture detector (Horiwitz et al. 1975). All results are reported on a wet tissue basis.

Results

Fortunately, most of the chlorinated hydrocarbons were present (Tables 9 - 12) at concentrations below analytical detection limits (0.01 ug/g for everything except PCB for which the detection limit was 0.1 ug/g). When residues were detected, the concentrations were very low and below existing guidelines for human consumption.

Fish from the Boulder River downstream of the town of Boulder and from Big Spring Creek most frequently contained detectable residues of chlorinated hydrocarbons. All six fish that were analyzed from the Boulder River contained detectable concentrations of DDE and three of those contained modest amounts of

Table 9. Concentrations of chlorinated hydrocarbons in fish taken from the Marias and Missouri Rivers during 1983.

Location & date	Species	Length (mm)	Weight (gm)	Residue concentration (ug/l)									
				DDE	DDD	DDT	PCB[a]	Dieldrin	BCH[b]	Lindane	HCB[c]	Endrin	HE[d]
Missouri River below Fort Peck Dam (May 3-10, 1983)	Rainbow trout	--	1770	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		--	1350	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		--	1680	<0.01	<0.01	<0.01	<0.10	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
		--	870	<0.01	<0.01	<0.01	<0.10	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
		--	2300	<0.01	<0.01	<0.01	<0.10	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
	Shovelnose sturgeon	--	850	0.02	<0.01	<0.01	<0.10	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
		--	1450	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		--	900	<0.01	<0.01	<0.01	<0.10	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
		--	820	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		--	500	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Marias River near Moffat (October 20, 1982)	Mountain whitefish	415	560	0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		423	760	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		400	875	0.03	<0.01	<0.01	0.16	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		420	540	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		426	780	0.03	<0.01	<0.01	0.15	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		375	480	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		418	670	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		395	620	0.02	<0.01	<0.01	0.14	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		300	300	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		331	350	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a]PCB denotes polychlorinated biphenyls.
[b]BCH denotes benzene hexachloride.
[c]HCB denotes hexachlorobenzene.
[d]HE denotes heptachlor epoxide.

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Table 10. Concentrations of chlorinated hydrocarbons in fish taken from the Missouri River during 1983.

Location & date	Species	Length (mm)	Weight (gm)	Residue concentration (ug/1)									
				DDE	DDD	DDT	PCB[a]	Dieldrin	BCH[b]	Lindane	HCB[c]	Endrin	HE[d]
Missouri River below Canyon Ferry Dam (April 21 & May 19, 1983)	Rainbow trout	340	426	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		292	318	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		401	653	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		470	1116	0.02	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		340	458	0.02	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		445	1057	0.01	<0.01	<0.01	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Missouri River below Holter Dam (May 6, 1983)	Rainbow trout	445	712	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		429	744	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		399	708	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		371	481	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		404	567	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		345	445	0.02	<0.01	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] PCB denotes polychlorinated biphenyls.

[b] BCH denotes benzene hexachloride.

[c] HCB denotes hexachlorobenzene.

[d] HE denotes heptachlor epoxide.

GP/war-34-5-3

Table 11. Concentrations of chlorinated hydrocarbons in fish taken from the Missouri and Madison Rivers during 1983.

Location & date	Species	Length (mm)	Weight (gm)	Residue concentration (ug/1)									
				DDE	DDD	DDT	PCB[a]	Dieldrin	BCH[b]	Lindane	HCB[c]	Endrin	HE[d]
Madison River below Hebgen Dam (June 6, 1983)	Rainbow trout	262	186	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		178	68	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		203	91	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		127	27	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		391	617	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		241	168	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Madison River below Ennis Powerhouse (June 6, 1983)	Brown trout	254	159	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		249	168	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		251	154	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Rainbow cutthroat hybrid	312	318	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		305	277	< 0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		333	372	0.01	<0.01	< 0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a]PCB denotes polychlorinated biphenyls.

[b]BCH denotes benzene hexachloride.

[c]HCB denotes hexachlorobenzene.

[d]HE denotes heptachlor epoxide.

GP/war-34-5-2

Table 12. Concentrations of chlorinated hydrocarbons in fish taken from the Boulder River downstream from Boulder and Big Spring Creek dowonstream from Lewistown.

Location & date	Species	Length (mm)	Weight (gm)	Residue concentration (ug/l) DDE	DDD	DDT	PCB[a]	Dieldrin	BCH[b]	Lindane	HCB[c]	Endrin	HE[d]
Boulder River near Boulder (May 16-17, 1983)	Whitefish	323	304	0.02	<0.01	0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		361	449	0.06	<0.01	0.01	0.22	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		361	422	0.01	<0.01	0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Brown trout	427	726	0.03	<0.01	0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		432	744	0.05	<0.01	0.01	0.17	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		419	853	0.04	<0.01	0.01	0.40	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Big Spring Creek near Lewistown (Nov. 24, 1981)	Rainbow trout	333	--	--	--	--	0.08	--	--	--	--	--	--
		343	--	--	--	--	0.07	--	--	--	--	--	--
	Longnose sucker	394	--	--	--	--	0.27	--	--	--	--	--	--

[a]PCB denotes polychlorinated biphenyls.

[b]BCH denotes benzene hexachloride.

[c]HCB denotes hexachlorobenzene.

[d]HE denotes heptachlor epoxide.

GP/war-34-5-4

PCB's (Table 11). Additionally, all three fish from Big Spring Creek contained detectable amounts of PCB (Table 11).

It is worth noting that a PCB spill resulting from leaking electrical transformers was reported at the Boulder River Hospital a short time prior to our sampling. There was also an incident at the Boulder sewage treatment plant during which several dozen waterfowl (primarily grebes) were found dead on the sewage lagoon. One of these was found to contain over 50 ug/g of DDE in breast fat. The detectable residues of DDE and PCB in trout from the Boulder River could be related to the incident at the Boulder sewage lagoon.

Acid Deposition: Monitoring of Lakes in Southwestern Montana

Acid deposition has been identified as one of our nation's high priority pollution problems. Sulfur dioxide and nitrogen oxides, originating primarily from burning of fossil fuels and from the metals smelting industry, form sulferic and nitric acids upon entering the atmosphere. These materials are then carried and deposited often hundreds of miles from their source.

Acid deposition may occur as rain or snow or as a fallout of dry material. The most severe cases of acid deposition have been documented in the industrial centers of the midwestern and northeastern United States and in northern Europe where hundreds of low alkalinity lakes have been affected. However, acid deposition has also been demonstrated to be occurring in other portions of the world, including the western United States.

Acid deposition in the form of acidic snowfall has recently been documented in southwestern Montana (SCS 1981; SCS 1982; SCS 1983). That portion of the state contains numerous alpine lakes, many of which overlie granitic substrates and thus have limited capacity to buffer atmospheric acids that may be deposited. Unfortunately, very little previous information has been collected on the chemical characteristics of these lakes. Consequently, we do not have a reference against which to gauge changes in water chemistry that may have occurred due to acid deposition.

Since 1981, the Region 3 office of the Montana Department of Fish, Wildlife and Parks has been conducting fishery surveys of lakes in southwestern Montana to aid in development of fishery management strategies, including fish stocking programs (Wells 1981; McMullin 1983; Oswald, unpublished).

So that we could begin to accumulate baseline information on the chemistry of alpine lakes, both McMullin during the summer of 1982 (13 lakes in both the East and West Pioneer Mountains) and Oswald during the summer of 1983 (11 lakes in the East Pioneer Mountains), were furnished with containers for collecting surface water samples (Tables 13-14 and Figs. 19-20). Additionally in 1983 we sampled 5 lakes in the West Pioneer Mountains and 15 lakes in the Beaverhead Mountains (Table 15 and Fig. 21). These latter 20 lakes were selected for monitoring because the U.S. Forest Service had collected water quality information on the same lakes in the early 1970's. Thus, there was an opportunity to compare present water quality to that which existed approximately a decade ago. Wells (1981) has also summarized fishery information on the 15 lakes in the Beaverhead Mountains as has McMullin (1983) on 13 lakes in the East and West Pioneers. This should prove to be useful future reference information, particularly in those lakes that support natural reproduction of fish.

Methods

Parameters measured at all lakes included pH, total alkalinity, hardness, calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, specific conductivity, and aluminum. Parameters measured in the field included pH (with a Corning model 620 pH meter), alkalinity (by titration with 0.020 N sulfuric acid and using bromo-cresol green, methyl-red indicator), hardness (by titration with 0.01 N EDTA and using Hach Man Ver-2 indicator powder pillows), and specific conductivity (with a YSI model 33 conductivity meter). The remaining

Table 13. Location, elevation, area, maximum depth and drainage outlet for thirteen alpine lakes monitored for water quality in the East and West Pioneer Mountains; samples collected September 3, 1982 by Steve McMullin.

Lake	Location	Elevation (ft)	Area (acres)	Maximum depth (ft)	Drainage outlet
Baldy	T3S R14W S1	8555	29	85	Pattengail Creek
Sand	T2S R17W S36	8277	42	58	Sand Creek
Black Lion	T2S R11W S31	8780	12	29	Boulder Creek
Elkhorn	T4S R11W S30	8680	12	25	Elkhorn Creek
Ferguson	T1N R12W S31	7528	17	48	Alder Creek
Foolhen	T1N R12W S29	7162	8	38	Alder Creek
Hopkins	T4S R12W S25	8884	13	45	Elkhorn Creek
Lower Schultz	T3S R11W S29	8520	6	8	Jacobsen Creek
Upper Schultz	T3S R11W S29	8680	8	12	Jacobsen Creek
Lower Stone	T2S R13W S5	8000	11	47	Pattengail Creek
Upper Stone	T2S R13W S6	8480	17	29	Pattengail Creek
Tahepia	T3S R11W S21	8920	16	20	Jacobsen Creek
Torrey	T4S R11W S21	8964	28	35	David Creek

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Table 14. Location, elevation, and drainage outlet for thirteen alpine lakes monitored for water quality in the East Pioneer Mountains; samples collected August 22-24, 1983 by Dick Oswald.

Lake	Location	Elevation (ft)	Drainage outlet
Abundance	T3S R11W S7	8660	Canyon Creek
Upper Gorge	T4S R11W S9	9160	Gorge Creek
Vera	T3S R11W S16	8720	Lion Creek
Canyon	T3S R11W S8	8392	Canyon Creek
Lion	T3S R11W S17	8860	Lion Creek
Waukena	T3S R11W S22	8666	Rock Creek
Tendoy	T4S R11W S4	9240	Willow Creek
Lower Gorge	T4S R11W S16	9140	Gorge Creek
Scott	T4S R12W S30	8660	Cat Creek
Grayling	T3S R11W S17	8660	Lion Creek
Crescent	T5S R11W S18	8780	Canyon Creek

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Figure 19. Alpine lakes in the West Pioneer Mountains monitored during the acid deposition baseline studies.

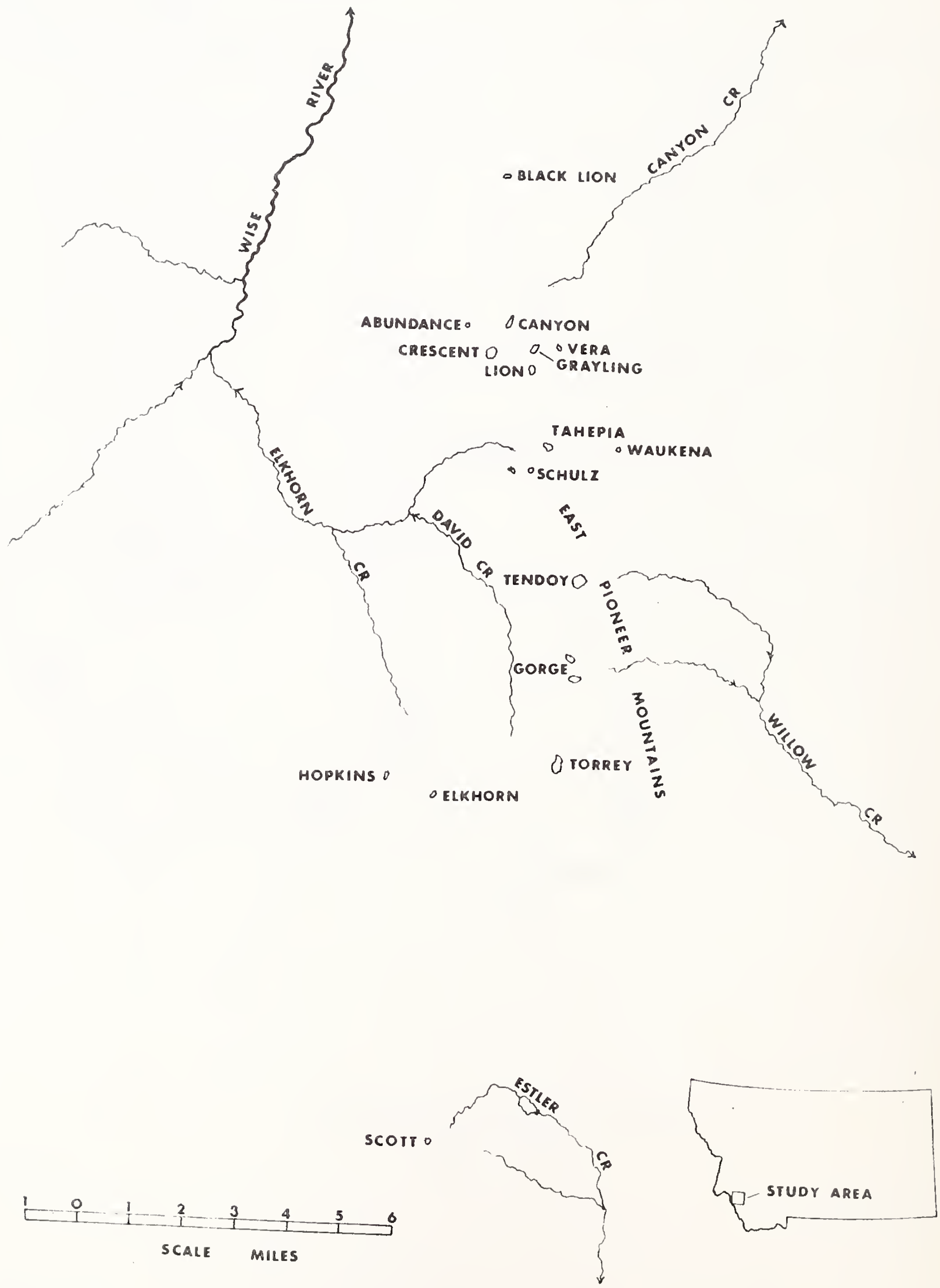

Figure 20. Alpine lakes in the East Pioneer Mountains monitored during the acid deposition baseline studies.

Table 15. Location, elevation, area, maximum depth and drainage outlet for twenty alpine lakes monitored for water quality in the West Pioneer and Beaverhead Mountains; samples collected August 22-24, 1983.

Lake	Location	Elevation (ft)	Area (acres)	Maximum depth (ft)	Drainage outlet
Hamby	T7S R17W S1	8092	39	33	Hamby Creek
Geneva	T7S R17W S2	8451	8	47	Hamby Creek
Berry	T7S R17W S24	8700	11	32	Berry Creek
Timberline	T7S R17W S24	9180	8	26	(closed)
Jahnke	T7S R16W S29	8760	11	16	Jahnke Creek
Ridge	T6S R17W S26	8449	9	32	Miner Creek
Lower Rock Island	T6S R17W S22	8325	20	19	Miner Creek
North Rock Island	T6S R17W S22	8350	10	8	Miner Creek
Upper Miner	T6S R17W S34	8029	42	60	Miner Creek
Upper Upper Miner	T6S R17W S34	8749	12	99	Miner Creek
Lower Slag-a-melt	T5S R17W S33	8316	8	17	Slag-a-melt Creek
Upper Slag-a-melt	T5S R27W S32	8740	16	75	Slag-a-melt Creek
Ajax	T6S R17W S7	8522	20	93	Big Swamp Creek
Little	T6S R17W S21	8730	13	29	Little Lake Creek
Lena	T6S R17W S32	8345	27	29	Big Swamp Creek
Sand	T2S R17W S36	8277	40	29	Sand Creek
Odell	T3S R13W S17	8340	34	18	Odell Creek
Baldy	T3S R14W S1	8555	29	43	Pattengail Creek
Bobcat	T2S R13W S33	8500	5	10	(closed)
Schwinegar	T3S R13W S8	8230	5	16	Lacy Creek

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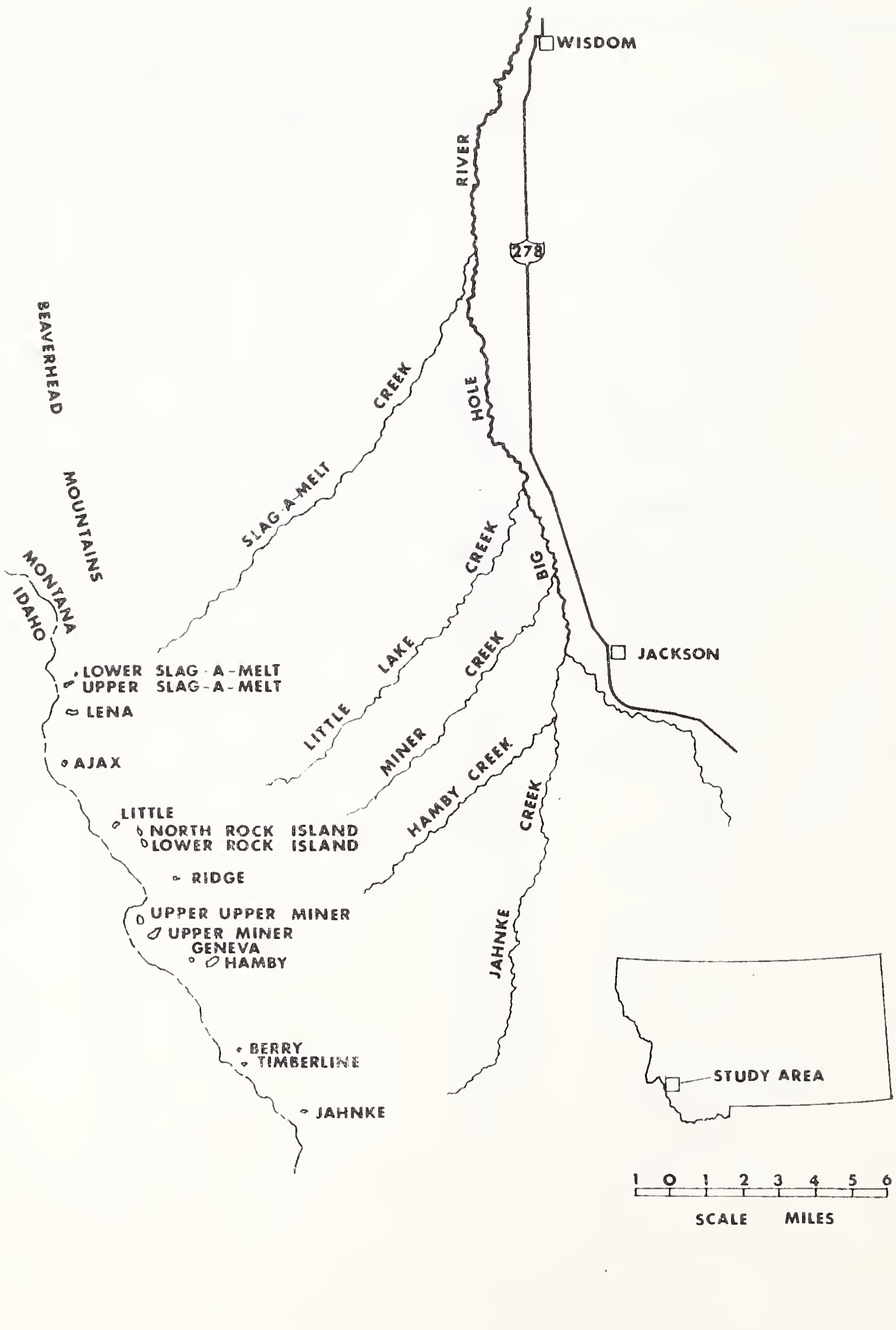

Figure 21. Alpine lakes in the Beaverhead Mountains monitored during the acid deposition baseline studies.

parameters were measured by the Chemistry Laboratory of the Montana Department of Health and Environmental Sciences using approved Environmental Protection Agency procedures (USEPA 1983).

For the twenty lakes that we monitored in 1983, water was taken from the surface, mid-water, and near the bottom with a Van Dorn sampler. We did this to determine if any of the parameters were stratified in the water column. Periphyton samples were also scraped from rocks or logs in each of these lakes and soft bodied algae were later identified to genera by Dr. Loren Bahls of the Water Quality Bureau, Montana Department of Health and Environmental Sciences.

Results

All of the 44 lakes surveyed had relatively low buffering capacities; 38 have total alkalinities of less than 20 mg/l (as $CaCO_3$), 30 were lower than 10 mg/l, and 13 contained 4 mg/l or less (Tables 16-20). The latter has been designated as the "extremely sensitive" threshold by EPA. The lowest alkalinity found was only 1 mg/l in Timberline Lake, a high elevation lake (9,180 ft) in the Beaverhead Mountains.

In general, lakes in the East Pioneer Mountains, northern ends of the West Pioneer Mountains (Alder Creek drainage) and Beaverhead Mountains (Slag-a-melt Creek drainage) had more buffering capacity than lakes in the southern ends of the West Pioneer Mountains (Pattengail Creek and Lacy Creek drainages) and Beaverhead Mountains (Hamby Creek and Jahnke Creek drainages). We do not have sufficient information at this time to determine whether this trend is due to natural differences in the chemistry of the watersheds or has some relation to the direction from which acid deposition enters Montana. Snow survey data indicate that atmospheric acids enter Montana from the southwest (SCS 1981; SCS 1982; SCS 1983), thus lakes located in the southern ends of mountain ranges could conceivably receive more acid deposition. This is worth exploring further.

In most of the lakes surveyed, calcium is the predominant cation and bicarbonate is the predominant anion (Tables 16-20) although sodium and calcium were equally abundant in the five lakes sampled in the southern end of the West Pioneer Range (Sand, Odell, Baldy, Bobcat, Schwinegar). Equivalents of cations and anions from a given location balanced well within the acceptable range of plus or minus one standard deviation, lending further credibility to the accuracy of the data.

Concentrations and values of chemical parameters measured in the 1970's were compared to those that we measured during 1983. In general, samples taken in 1983 were slightly higher in sodium and magnesium; slightly lower in calcium, alkalinity and chloride; considerably lower in sulfate; and similar in pH (Tables 21-22). It is tempting to conclude that the lower alkalinity is due to acid deposition that has occurred over the last decade; however, this conclusion is not justified for a number of reasons. Any number of factors including timing of ice-off, spring turnover, run-off, biological productivity peaks and other factors related to climate could influence the amounts and distribution of the various chemical constituents that we measured. Over the next several years, we intend to select three or four lakes and conduct more intensive monitoring so that we can distinguish between diurnal or seasonal changes and long-term trends.

Table 16. Concentrations of major cations and anions in surface, mid and bottom waters from eight alpine lakes in the Beaverhead Mountains; samples were taken on August 18, 1983 (nd indicates not detected).

			Major cations (mg/l)				Major anions (mg/l)			
Lake	Sample depth[a]	pH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}[b]	Cl^{-}	SO_4^{2-}	NO_3^{-}
Ridge	S	6.86	1.1	0.2	0.6	0.1	4.3	0.1	0.4	nd
	M	6.77	1.0	0.2	0.7	0.1	4.4	0.1	0.4	nd
	B	6.72	0.9	0.4	0.7	0.3	4.5	0.1	0.4	0.01
Upper Upper Miner	S	6.81	1.0	0.6	0.5	0.1	5.4	0.1	0.3	nd
	M	6.70	0.8	0.5	0.5	0.1	5.1	0.1	0.3	nd
	B	6.59	0.8	0.5	0.5	0.1	5.0	0.1	0.3	nd
Upper Miner	S	6.99	1.3	0.8	0.6	0.2	8.3	0.1	0.3	0.01
	M	6.96	1.2	0.8	0.6	0.2	8.7	0.1	0.4	nd
	B	6.71	1.3	0.8	0.6	0.2	9.1	0.1	0.5	nd
Geneva	S	6.98	0.9	0.4	0.4	0.1	5.1	0.1	0.4	nd
	M	6.78	1.0	0.4	0.4	0.1	4.5	0.1	0.2	nd
	B	6.60	1.0	0.4	0.4	0.1	4.5	0.1	0.2	nd
Hamby	S	6.92	1.0	0.4	0.4	0.1	4.9	0.1	0.2	nd
	M	6.66	1.1	0.3	0.4	0.1	4.9	0.1	0.2	nd
	B	6.66	1.1	0.3	0.4	0.1	4.9	0.1	0.1	nd
Berry	S	6.66	0.7	0.3	0.4	0.1	2.8	0.1	0.2	nd
	M	6.72	0.6	0.3	0.4	0.1	2.8	0.1	0.3	nd
	B	6.55	0.6	0.3	0.4	0.1	3.3	0.1	0.4	nd
Timberline	S	6.34	0.3	0.2	0.3	0.1	1.1	0.1	0.2	0.04
	M	6.22	0.3	0.2	0.2	0.1	1.2	0.1	0.3	0.03
	B	6.24	0.2	0.2	0.3	0.1	1.2	0.1	0.2	0.03
Jahnke	S	7.01	1.0	0.7	0.5	0.2	7.2	0.1	0.3	nd
	M	6.97	1.1	0.7	0.5	0.1	7.3	0.1	0.2	nd
	B	6.96	1.1	0.7	0.5	0.2	7.2	0.1	0.2	nd

[a] S, M and B indicate surface, midwater and bottom respectively.

[b] Total alkalinity as $CaCO_3$.
GP/war-12-3

Table 17. Concentrations of major cations and anions in surface, mid and bottom waters from seven alpine lakes in the Beaverhead Mountains; samples were taken on August 17-18, 1983(nd indicates not detected).

			Major cations (mg/l)				Major anions (mg/l)			
Lake	Sample depth[a]	pH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}[b]	Cl^{-}	SO_4^{2-}	NO_3^{-}
Lower Slag-a-Melt	S	7.21	1.8	0.3	0.7	0.3	10.7	0.1	0.2	nd
	M	8.09	2.3	0.3	0.8	0.3	10.9	0.1	0.1	nd
	B	7.52	2.6	0.4	0.8	0.4	10.7	0.1	0.1	nd
Upper Slag-a-Melt	S	7.16	2.6	0.5	0.8	1.0	11.3	0.1	1.2	0.01
	M	7.12	2.8	0.5	0.7	1.0	12.1	0.1	1.3	nd
	B	7.13	3.1	0.6	0.8	1.1	12.9	0.1	1.5	nd
Lena	S	7.31	1.8	0.4	0.8	0.6	8.9	0.1	0.3	nd
	M	7.44	1.8	0.4	0.7	0.6	9.1	0.1	0.3	nd
	B	6.81	2.0	0.5	0.8	0.7	10.7	0.2	0.3	nd
Ajax	S	6.81	1.2	0.1	0.5	0.1	6.1	0.2	0.2	0.03
	M	6.80	1.8	0.1	0.6	0.1	6.8	0.1	0.2	nd
	B	6.56	1.8	0.2	0.2	0.1	6.8	0.1	0.2	nd
Little	S	7.22	1.8	0.1	0.4	0.1	7.1	0.1	0.1	nd
	M	6.99	2.0	0.1	0.1	0.1	7.2	0.1	0.2	nd
	B	7.24	2.0	0.1	0.4	0.1	7.1	0.1	0.1	nd
North Rock Island	S	7.57	5.0	0.2	0.6	0.1	18.2	0.1	0.2	nd
	M	7.33	5.1	0.3	0.7	0.1	18.2	0.1	0.3	0.01
	B	7.34	5.2	0.2	0.7	0.1	18.7	0.1	0.2	nd
Lower Rock Island	S	7.46	4.3	0.2	0.7	0.1	14.9	0.1	0.4	nd
	M	7.42	4.4	0.3	0.7	0.1	14.9	0.1	0.1	nd
	B	7.28	4.5	0.2	0.7	0.1	15.6	0.1	0.3	nd

[a] S, M and B indicate surface, midwater and bottom respectively.

[b] Total alkalinity as $CaCO_3$.

GP/war-12-2

Table 18. Concentrations of major cations and anions in surface, mid and bottom waters from twenty alpine lakes in the West Pioneer Mountains; samples were taken on August 17, 1983 (nd indicates not detected).

			Major cations (mg/l)				Major anions (mg/l)			
Lake	Sample depth[a]	pH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}[b]	Cl^{-}	SO_4^{2-}	NO_3^{-}
Sand	S	7.04	1.5	0.3	1.3	0.2	7.3	0.2	0.7	nd
	M	6.80	1.5	0.2	1.3	0.2	7.2	0.2	0.8	nd
	B	6.52	1.5	0.3	1.3	0.3	7.3	0.2	0.8	nd
Bobcat	S	6.67	0.6	0.2	0.6	0.4	3.7	0.1	0.6	nd
	M	6.66	0.5	0.1	0.8	0.4	3.7	0.2	0.6	nd
	B	6.62	0.6	0.2	1.0	0.4	3.8	0.1	0.4	0.01
Baldy	S	6.78	1.1	0.2	0.8	0.2	4.9	0.1	0.6	nd
	M	6.83	1.2	0.2	0.8	0.2	5.2	0.1	0.6	nd
	B	6.51	1.2	0.2	0.8	0.2	5.2	0.1	0.6	nd
Schwinegar	S	6.80	1.4	0.3	1.2	0.2	7.0	0.2	0.7	0.01
	M	6.98	1.4	0.3	1.3	0.2	6.5	0.2	0.8	nd
	B	6.44	2.6	0.4	0.8	0.4	11.6	0.2	1.3	nd
Odell	S	6.87	1.1	0.3	1.1	0.2	4.9	0.2	0.5	nd
	M	6.74	1.1	0.2	1.2	0.2	4.9	0.2	0.4	0.01
	B	6.29	1.2	0.2	1.1	0.2	5.7	0.2	0.8	0.02

[a] S, M and B indicate surface, midwater and bottom respectively.

[b] Total alkalinity as $CaCO_3$.

GP/war-12-1

Table 19. Specific conductance, pH and concentrations of major cations and anions in surface waters from thirteen alpine lakes in the East and West Pioneer Mountains; samples collected September 3, 1982 by Steve McMullin.

Lake	Specific conductance (umhos/cm²)	pH[a]	Major cations (mg/l)				Major anions (mg/l)			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}[b]	Cl^{-}	SO_4^{2-}	NO_3^{-}
Baldy	13	6.04	0.7	0.2	0.4	0.1	3.7	0.9	2.2	1.12
Sand	15	6.22	0.8	0.2	0.6	0.1	4.5	0.2	1.2	0.05
Black Lion	29	6.85	2.9	0.8	0.3	0.2	11.9	0.3	1.3	0.43
Elkhorn	14	6.14	0.9	0.1	0.4	0.1	4.9	0.5	1.2	0.23
Ferguson	65	6.90	6.8	1.8	1.5	0.3	24.9	1.5	8.9	0.49
Foolhon	88	7.28	10.7	2.2	3.8	0.4	33.8	0.1	0.9	0.05
Hopkins	18	6.10	1.0	0.1	0.5	0.1	6.9	1.1	1.2	0.04
Lower Schultz	23	6.75	2.0	0.4	0.4	0.2	9.8	0.7	1.2	0.59
Upper Schultz	40	7.13	4.1	0.8	0.7	0.2	21.2	0.1	0.6	0.05
Lower Stone	13	5.68	0.3	0.2	0.4	0.2	3.5	0.1	0.1	0.05
Upper Stone	11	5.90	0.4	0.2	0.5	0.2	3.1	1.3	2.0	0.59
Tahepia	20	6.47	1.5	0.3	0.5	0.2	7.8	1.0	1.7	0.49
Torrey	19	6.41	1.9	0.3	0.2	0.1	7.3	0.5	1.7	0.67

[a] pH measurements were made in the laboratory several days after the samples were taken.

[b] Total alkalinity as $CaCO_3$.

GP/war-34-7-2

Table 20. Specific conductance, pH and concentrations of major cations and anions in surface waters from eleven alpine lakes in the East Pioneer Mountains; samples collected August 22-24, 1983 by Dick Oswald.

Lake	Specific conductance (umhos/cm²)	pH[a]	Major cations (mg/l)				Major anions (mg/l)			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}[b]	Cl^{-}	SO_4^{2-}	NO_3^{-}
Abundance	11	7.51	0.6	0.2	0.3	0.2	4.5	0.9	1.0	1
Upper George	13	6.90	1.2	0.2	0.3	0.1	6.5	0.5	1.1	1
Vera	25	6.99	2.6	0.7	0.5	0.1	16.2	0.5	1.7	1
Canyon	43	7.30	3.9	1.7	0.4	0.1	26.1	0.5	1.3	1
Lion	32	7.32	3.3	0.9	0.3	0.1	19.7	0.5	1.4	1
Waukena	22	7.10	2.1	0.4	0.4	0.1	12.3	1.0	1.0	1
Tendoy	16	6.80	1.5	0.3	0.5	0.1	8.4	0.5	1.0	1
Lower George	19	6.90	1.6	0.3	0.6	0.1	9.7	0.5	1.6	1
Scott	40	6.97	3.7	0.9	0.8	0.2	22.1	0.7	2.2	1
Greyling	36	7.10	3.3	0.9	0.4	0.1	20.8	0.5	1.4	1
Crescent	17	6.92	1.4	0.4	0.4	0.1	8.8	0.5	1.4	1

[a] pH measurements were made in the laboratory several days after the samples were taken.

[b] Total alkalinity as $CaCO_3$.

GP/war-34-7-1

Table 21. Comparison of major cations and anions in surface water from twenty alpine lakes in the West Pioneer and southern Bitterroot Mountains; samples were collected in the early 1970's and again in 1983 (nd indicates not detected).

	Major cations (mg/l)								Major anions (mg/l)							
	Ca^{2+}		Mg^{2+}		Na^{+}		K^{+}		HCO_3^-		Cl^-		SO_4^{2-}		NO_3^-	
	70's	83	70's	83	70's	83	70's	83	70's	83	70's	83	70's	83	70's	83
Hamby	1.6	1.0	0.2	0.4	0.3	0.4	--	0.1	10	5	0.1	0.1	nd	0.2	--	nd
Geneva	1.8	0.9	0.1	0.4	0.2	0.4	--	0.1	8	5	0.4	0.1	nd	0.4	--	nd
Berry	1.2	0.7	0.2	0.3	0.2	0.4	--	0.1	6	3	0.3	0.1	nd	0.2	--	nd
Timberline	0.6	0.3	0.1	0.2	0.2	0.3	--	0.1	3	1	0.7	0.1	nd	0.2	--	0.04
Jahnke	1.8	1.0	0.7	0.7	0.4	0.5	--	0.2	11	7	0.3	0.1	nd	0.3	--	nd
Ridge	1.2	1.1	0.1	0.2	0.3	0.6	--	0.1	6	4	1.0	0.1	nd	0.4	--	nd
Lower Rock Island	6.4	4.3	0.0	0.2	0.4	0.7	--	0.1	19	15	0.2	0.1	2.1	0.4	--	nd
North Rock Island	7.4	5.0	0.0	0.2	0.4	0.6	--	0.1	20	18	0.3	0.1	2.9	0.2	--	nd
Upper Miner	2.2	1.3	1.6	0.8	0.5	0.6	--	0.2	10	8	0.3	0.1	2.1	0.3	--	0.01
Upper Upper Miner	1.4	1.0	0.1	0.6	0.3	0.5	--	0.1	7	5	0.2	0.1	0.0	0.3	--	nd
Lower Slag-a-Melt	3.8	1.8	0.0	0.3	0.6	0.7	--	0.3	12	11	0.2	0.1	0.4	0.2	--	0.01
Upper Slag-a-Melt	3.4	2.6	0.0	0.5	0.5	0.8	--	1.0	12	11	0.1	0.1	0.0	1.2	--	0.01
Ajax	2.8	1.2	0.0	0.1	0.3	0.5	--	0.1	8	6	0.1	0.2	0.4	0.2	--	0.03
Little	4.6	1.8	0.0	0.1	0.2	0.4	--	0.1	12	7	0.3	0.1	0.8	0.1	--	nd
Lena	3.2	1.8	0.0	0.4	0.5	0.8	--	0.6	12	9	0.3	0.1	0.8	0.3	--	nd
Sand	2.4	1.5	0.2	0.3	1.2	1.3	--	0.2	8	7	0.3	0.2	3.5	0.7	nd	nd
Odell	2.4	1.1	0.1	0.3	1.0	1.1	--	0.2	11	5	0.5	0.2	4.0	0.5	nd	nd
Baldy	1.2	1.1	0.0	0.2	0.8	0.8	--	0.2	7	5	0.1	0.1	0.7	0.6	nd	nd
Bobcat	1.6	0.6	0.3	0.2	1.0	0.6	--	0.4	6	4	0.3	0.1	4.0	0.6	nd	nd
Schwinegar	1.2	1.4	1.2	0.3	1.2	1.2	--	0.2	8	7	0.8	0.2	5.0	0.7	nd	nd

[a]1971-73 samples collected by the U.S. Forest Service and analyzed by the Water Quality Bureau of the Montana Department of Health and Environmental Sciences.

[b]Denotes lakes samples collected in 1971; the remaining lakes were sampled in 1973.

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Table 22. Comparison of measurements of pH, total alkalinity and specific conductivity of twenty alpine lakes in the West Pioneer and Beaverhead Mountains; samples were collected in the early 1970's and again in 1983.[a]

Lake	pH 1971 or 73	pH 1983	Alkalinity (mg/l as $CaCO_3$) 1971 or 73	Alkalinity (mg/l as $CaCO_3$) 1983	Conductivity (umhos/cm^2) 1971 or 73	Conductivity (umhos/cm^2) 1983
Hamby	6.7	6.9	8	4	11	13
Geneva	6.7	7.0	7	4	11	13
Berry	6.7	6.7	5	2	8	13
Timberline	6.3	6.3	2	1	6	10
Jahnke	6.9	6.9	9	6	15	18
Ridge	6.5	6.9	5	4	9	14
Lower Rock Island	7.3	7.5	16	12	33	22
North Rock Island	7.2	7.6	17	15	36	25
Upper Miner	6.8	7.0	8	7	18	13
Upper Upper Miner	6.5	6.8	6	4	12	12
Lower Slag-a-melt	6.9	7.2	10	9	23	22
Upper Slag-a-melt	7.0	7.2	10	9	24	25
Ajax	6.8	6.8	7	5	14	20
Little	7.1	7.2	10	6	20	14
Lena	7.0	7.3	10	7	21	18
Sand	6.8[b]	7.0	7	6	19	21
Odell	6.8[b]	6.9	9	4	14	16
Baldy	6.9[b]	6.8	6	4	18	16
Bobcat	6.5[b]	6.7	5	3	12	16
Schwinegar	6.8[b]	6.8	7	6	16	17

[a]1971-73 samples collected by the U.S. Forest Service and analyzed by the Water Quality Bureau of the Montana Department of Health and Environmental Sciences.

[b]Denotes lake samples collected in 1971; the remaining lakes were samples in 1973.

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For the most part, there was very little difference between the concentrations of common ions in a given lake at the surface, mid-water, or near the bottom. The pH was slightly lower near the bottom of some lakes than in overlying water, indicating a more reducing environment near the bottom; however, the difference was usually small and in some lakes did not exist.

The majority of lakes in the Beaverhead and West Pioneer Mountains had total recoverable aluminum concentrations below 0.1 mg/l. However, Upper Miner had 0.86 mg Al/l at the surface, Ridge contained 0.23 mg Al/l at the bottom and Lower Slag-a-melt contained 0.41 mg Al/l at the bottom.

Aluminum solubility increases rapidly as the pH drops from 7 to 5. Loss of fish in lakes affected by acid deposition has been ascribed to aluminum toxicity (Cronan and Schofield 1979). Sublethal affects of aluminum in brook trout growth have been noted from 0.1 - 0.3 mg Al/l. The three lakes described above therefore contained aluminum concentrations that are in a range that would be expected to affect growth of brook trout. Conceivably, aluminum may be naturally present in some alpine lakes at concentrations that limit fish growth.

A wide variety of algae were present in the 20 alpine lakes monitored in the Beaverhead Mountains. Identified (Table 23) were 21 genera of green algae (Chlorophyta), 2 genera of yellow-green algae (Chrysophyta), 10 genera of blue-green algae (Cyanophyta), and one genera of dinoflagellates (Pyrrophyta). Of the twenty lakes sampled, 85% contained greens, 20% yellow greens, 85% blue greens and 10% dinoflagellates. (Bacillariophyta) were present in all twenty lakes sampled, but these have not yet been identified to genera.

There was no apparent trend between lake pH or alkalinity and genera of algae present (Table 24). The two lakes having the lowest alkalinities (Timberline and Berry) supported conspicuously low numbers of algal genera; however, there were several other lakes with higher pH's and alkalinities that also had few algal genera present. Thus, it is not apparent that the reduced diversity was the result of increased acidity. Algae of the Chrysophyta division, which are extremely sensitive to acid conditions (Stokes 1984), were absent in all but two lakes.

Diatoms have also proven to be sensitive indicators of acidity in some lakes (Stokes 1984). However, diatoms collected during this survey have not yet been identified. Future identification of the diatoms may reveal a good indicator species for gauging changing acidity in Montana's alpine lakes.

The pH measurements that we performed in the field unfortunately were invalidated due to the fact that we later learned that the pH probe we were using does not respond to low ionic strength solutions. Therefore, the pH values reported in the text are for laboratory measurements in which a probe specifically designed for low ionic strength solutions was employed. It should be pointed out that laboratory measurements of pH taken several weeks after samples are collected may be altered by biological activity occurring within the sample or by the dissolution of atmospheric carbon dioxide into the water. Therefore, measurements of pH should ideally be taken in the field within a few hours after sampling. Interpreters of the pH measurements reported should take this into account.

Table 23. Abundance of diatoms and genera of soft bodied (non-diatom) algae in samples taken from alpine lakes in the Beaverhead Mountains, Montana[a].

Family and genera	Lake									
	Ajax	Baldy	Barry	Bobcat	Geneva	Hamby	Jahnke	Lena	Little	Lower Rock Island
Bacillariophyta (diatoms)										
All genera	A	VC	C	C	C	VA	VC	VC	R	A
Chlorophyta (green algae)										
Ankistrodesmus	C							C		
Bulbochaete		C				C	VC	C		C
Chaetosphaeridium										
Closterium										
Cosmarium								R		
Euastrum					R	R				
Gloeocystis		C		C						
Microspora										
Mougeotia						C	C	VC		
Oedogonium		VC	C	VC	C	C	VC			
Oocystis		VC								
Penium										
Pleurotaenium										
Quadrigula										
Scenedesmus								R		
Sphaerocystis		C		VC				R	R	
Staurastrum								R		
Stigeoclonium		A						VC		
unknown colonial green		VC								
unknown filamentous green							R			
Zygnema		C				C				
Chrysophyta (yellow-green algae)										
Dinobryon										
Tribonema						R				
Cyanophyta (blue-green algae)										
Anabaena	VA			C		R				C
Anacystis										
Calothrix					R					
Dichothrix						C				
Merismopedia										
Microcystis										
Nostoc										
Oscillatoria				R					C	
Phormidium					C		C		A	
Tolypothrix			VA		VA	A	C	A		A
Pyrrophyta (dinoflagellates)										
Glenodinium				R						

[a]Abundance rating based on the number of algal cells per field of view at 100x magnification; R denotes rare (1 or less); C denotes common (2-4), VC denotes very common (5-10), A denotes abundant (11-99), VA denotes very abundant (100 or more).

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Table 23 (continued). Abundance of diatoms and genera of soft bodied (non-diatom) algae in samples taken from alpine lakes in the Beaverhead Mountains, Montana[a].

Family and genera	Lake									
	Lower Slag-a-melt	North Rock Island	Odell	Ridge	Sand	Schwinegar	Timber-line	Upper Miner	Upper Slag-a-melt	Upper Upper Miner
Bacillariophyta (diatoms)										
All genera	A	R	VC	VC	VA	A	C	VC	VC	VC
Chlorophyta (green algae)										
Ankistrodesmus										
Bulbochaete	C				R	C				
Chaetosphaeridium	VC									
Closterium						C				
Cosmarium	VC		C	R	R	C		R		
Euastrum	R					R				
Gloeocystis			VC		VA					
Microspora				R						
Mougeotia			C			C		VA		C
Oedogonium	C		A	C	C	C				C
Oocystis			VC		VC					
Penium	R					R				
Pleurotaenium						R				
Quadrigula			C		C					
Scenedesmus					R					
Sphaerocystis					VC					
Staurastrum										
Stigeoclonium										
unknown colonial green										
unknown filamentous green										
Zygnema	R					R		C		
Chrysophyta (yellow-green algae)										
Dinobryon			R							
Tribonema										
Cyanophyta (blue-green algae)										
Anabaena			R	C		C		R		
Anacystis						C				
Calothrix				C			R			
Dichothrix			C		VC			VC		
Merismopedia						R				
Microcystis					VA					
Nostoc					VC	C				
Oscillatoria	C									
Phormidium		C								
Tolypothrix	VA			C	C					A
Pyrrophyta (dinoflagellates)										
Glenodinium			C							

[a]Abundance rating based on the number of algal cells per field of view at 100x magnification; R denotes rare (1 or less); C denotes common (2-4), VC denotes very common (5-10), A denotes abundant (11-99), VA denotes very abundant (100 or more).

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Table 24. Numbers of genera of soft bodied algae present from each of several algal divisions in samples taken from alpine lakes in the Beaverhead Mountains, Montana.

Lake	Total alkalinity (mg/l as $CaCO_3$)	Surface pH	Genera of algae in each division				
			Diatom[a]	Green	Yellow-green	Blue-green	Dinoflagellate
Timberline	1	6.3	*	--	--	1	--
Berry	2	6.7	*	1	--	1	--
Bobcat	3	6.7	*	3	--	2	1
Ridge	4	6.9	*	3	--	3	--
Hamby	4	6.9	*	5	1	3	--
Odell	4	6.9	*	6	1	2	1
Baldy	4	6.8	*	8	--	--	--
Geneva	4	7.0	*	2	--	3	--
Upper-Upper Miner	4	6.8	*	2	--	1	--
Ajax	5	6.8	*	1	--	1	--
Schwineger	6	6.8	*	9	--	4	--
Sand	6	7.0	*	8	--	4	--
Jahnke	6	6.9	*	4	--	2	--
Little	6	7.2	*	1	--	2	--
Upper Miner	7	7.0	*	3	--	2	--
Lena	7	7.3	*	8	--	1	--
Upper Slag-a-melt	9	7.2	*	--	--	--	--
Lower Slag-a-melt	9	7.2	*	7	--	2	--
Lower Rock Island	12	7.5	*	1	--	3	--
N. Rock Island	15	7.6	*	--	--	1	--

[a]Diatoms were present in all lakes but have not yet been identified to genera.

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Wells (1981) assessed the fish spawning potential of several of the lakes that we sampled in the Beaverhead Mountains. He concluded that Hamby, Lower Rock Island, and Jahnke have good potential for natural reproduction; Geneva, Little, and Ridge only fair potential; and Lower Slag-a-melt, Upper Miner, Upper Upper Miner, Upper Rock Island, Upper Slag-a-melt, Ajax, Berry, Lena, and Timberline have marginal, poor, or no potential for spawning.

Reduced reproduction rates are of the first symptoms of excessive lake acidification experienced by fish populations (Fritz 1980). Menendez (1976) showed that hatchability of brook trout eggs was reduced at all pH levels below 6.5. Of the lakes in the Beaverhead Mountains that support natural reproduction of brook trout, Hamby and Upper Miner had pH values near the bottom that are already near the threshold (6.5) for reproduction, 6.66 and 6.71 respectively. These natural reproducing populations will be threatened if the pH of these lakes continues to decrease. These populations should be monitored every 2-3 years to determine reproductive success.

Metals in Road Slag Leachate

Road sanding crews in Granite and Deer Lodge Counties commonly use slag from the Anaconda smelter to improve road traction during winter driving conditions. The use of this material has recently been the subject of much concern, particularly among cabin and home owners in the Georgetown Lake area and along Rock Creek who fear that slag entering the lake or creek may damage fish populations.

Experiments conducted by EPA in 1983 (unpublished data) during which slag was acidified, showed that leach water was enriched in iron, zinc, copper, arsenic, lead, chromium and cadmium.

We conducted similar experiments during 1982, but using slag collected from roads in the Rock Creek drainage. Our objectives were to determine if metals concentrations in slag leachate from Rock Creek slag were similar to those found using Georgetown Lake slag (at similar spike rates) and to observe if concentration of metals in leachate increased linearly as slag concentration increased.

Methods

Dried slag of the same texture as that used on the roads was spiked in distilled water at concentrations of 0.5, 1.0, 5.0, 10.0 and 50.0 mg/l and swirled on a mechanical table at 140 rpm for 24 h; each slag concentration was prepared in triplicate. Samples were finally filtered and total recoverable metals concentration were determined by hydride generation and atomic absorption spectrophotometry for arsenic, by cold vapor atomic absorption spectrophotmetry for mercury, and by atomic emission spectroscopy for cadmium, copper and zinc. Results are reported on a dry weight basis.

Results

Arsenic, copper, cadmium and zinc were all enriched in slag leachate water (Fig. 22). Copper and zinc, in particular, increased in proportion to the concentration of slag. The relationship was highly linear for all four metals; correlation coefficients ranged from 0.87 for cadmium to 0.97 for arsenic.

Moving waters of any appreciable size would likely provide sufficient dilution to prevent metals that could originate from road slag from exceeding criteria for protection of aquatic life. However, a problem could result in lakes, such as Georgetown Lake, where the turnover rate is very slow. The Department of Health and Environmental Sciences has recommended that slag not be used within a quarter mile of Georgetown Lake, or within 100 yards of bridges. This recommendation appears prudent in view of the above.

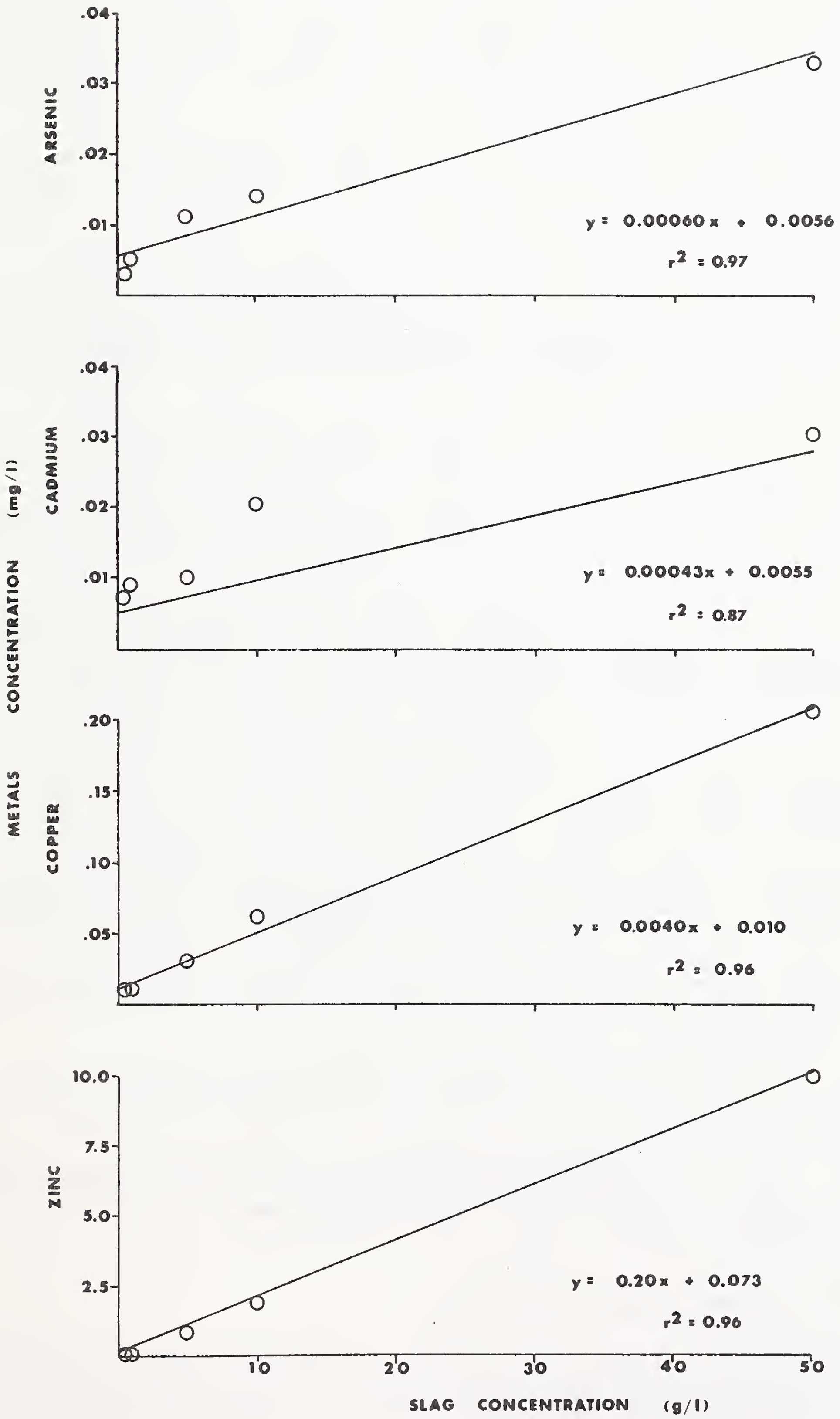

Figure 22. Relationship between metals concentration in water and slag concentration during slag leaching experiments.

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Waters referred to:

Name	State Water Code
Big Spring Creek	16-0300
Boulder River	10-0804
Fred Burr Creek	06-2356
German Gulch	06-2470
Grasshopper Creek	01-3100
Lake Creek	11-3580
Marias River	14-3240
Madison River Sec 01	13-3400
Madison River Sec 02	13-3440
Missouri River Sec 05	16-2420
Missouri River Sec 08	17-4880
Missouri River Sec 09	17-4896
Missouri River Sec 10B	17-4914
Silver Creek	17-6704
Yellowstone River Sec 04	22-7015

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